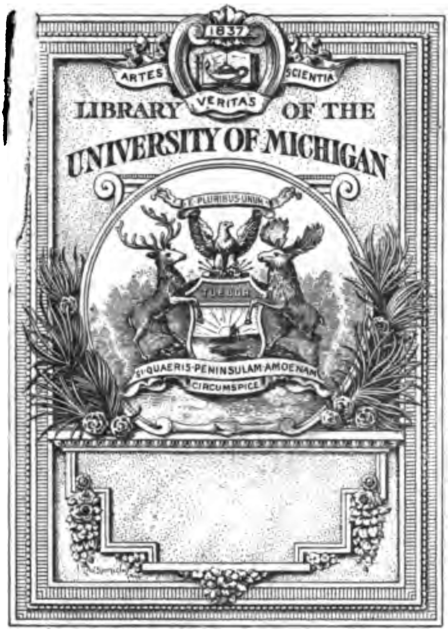
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THE SCIENTIFIC STEEL WORKER

A PRACTICAL MANUAL

For Steel Workers and Blacksmiths. ¶ The Art of Working Steel Thoroughly Explained. ¶ Also Steel Working Receipts and Mechanical Tables for Making Rings of All Sizes of Iron, Steel and Angle Iron

BY OZRO A. WESTOVER

Wheeling News Litho Co.,
Wheeling, W. Va.

Yours Truly
O. A. Westover

Preface

In presenting the second edition of this work to the craft, it has been my aim to give my readers thorough and complete instructions in the art of working steel. Books of a theoretical and technical character are of little value to a practical man. For the benefit of my brother craftsmen and all those who wish to gain a thorough knowledge of modern practical and scientific steel working, I will endeavor to give the best methods of Forging, Annealing, Hardening, Tempering, Case Hardening, and Welding the King of Metals (Steel), and to point out the chief causes of bad results and how to avoid them, and to do so in a plain, concise manner, eliminating all technical terms, superflous words, egotistical anecdotes; and hope my efforts will meet with the approval of the world's best Steel Workers and Steel Makers, and be of value to every blacksmith and steel worker, machinist and boiler maker.

The writer is a practical blacksmith and an expert steel worker of seventeen years' experience at the anvil and hardening furnace, has worked in several up-to-date shops and with several of the best steel workers in America. I do not claim to know it all or to be the only man who knows how to work steel properly (there are others). All I claim to be is one of the world's best Steel Workers. The first edition of this

work is all sold. It was only a small book of 112 pages with no illustrations, yet it met with the approval of all readers. The price of the first edition was $1.50, and I have hundreds of unsolicited testimonials from prominent men who know a good thing when they see it. Many of them say they would not be wothout the book for $25.00, and all are loud in their praise of "The Scientific Steel Worker." Letters of that sort and the steady increase in the sales of the first edition has prompted me to write the second, which is a much larger and better book, more complete in many respects; and contains many new tables and rules which have never before appeared in print. Since writing the first edition, the writer has worked in a few up-to-date shops and gathered considerable valuable knowledge. In this edition I give the reader the benefit of all I know pertaining to working steel. I am indebted to Brother A. S. McCarl, of 900 Corbet St., Portland, Oregon, for the new and valuable rules for working angles. These rules have never before been printed, but Mr. McCarl has used them for several years on all kinds and sizes of angles and they are absolutely correct and well worth ten times the price of the book to all angle smiths. Mr. McCarl is now foreman blacksmith in a ship yard at Portland and has been foreman for several large companies in America and Great Britain. This work cannot but be of value to all who wish to improve themselves in the art of working steel and iron. To those who want to learn I dedicate this book.

The Scientific Steel Worker

JUDGING TOOL STEEL.

All steel workers are judges of steel to some extent, some can only manage to tell steel from iron, others can discriminate between high and low carbon steels, while the up-to-date steel worker, who has made a study of this peculiar and wonderful metal; can by various tests determine the carbon content of steel, sufficiently accurate for all practical purposes.

To become a good judge of steel requires close observation and some careful experimenting with several different grades of steel of a known carbon content. To make the necessary experiments the operator should obtain eight pieces of steel about eight inches long. The carbon content of these pieces should be 60, 70, 80, 90, 100, 110, 120 and 150 points. The first thing to be done is to mark the per cent of carbon content on each piece close to the end. Then with a sharp chisel, file or hacksaw, nick each bar about one inch from the other end, on one side only, and break them off, being careful to keep the fractured ends dry and perfectly clean. Place the short pieces in rotation according to the carbon content. If these pieces are placed in an air-tight box with a glass cover they will retain their original appearance for years and will be

of value for future reference. These fractures should be carefully examined with a magnifying glass. It will be readily seen that there is a great difference in the appearance of each piece. The 60 carbon steel will be coarse grained and rough on the fractured surface. You will also notice that there is a thin skin or covering on the steel which is composed of oxide of iron or decarbonized steel. This skin on 60 carbon steel will be about 1-64 of an inch thick, (nick the steel only on one side, for the skin cannot be seen on the side that was nicked). All steel as it comes from the mill has this skin or decarbonized surface which is caused by the chemical action of the air upon the hot steel while it is being worked, and is very much thicker on annealed steel; the fractured end of the 70 carbon steel will be a trifle smoother with a closer grain, and the decarbonized skin will be thinner, the same difference will be noticeable with each specimen, the higher the carbon the thinner the skin and the smoother the fractured end will be and vice versa. The lower the carbon the thicker the skin and the coarser the grain. Good steel will show an even grain all through. Inferior steel will have dead looking spots in it, especially in the center, and some poor steel has bright sparkling particles in it which can easily be discerned with the naked eye. Watch all these points closely and remember how each fracture appears.

The fracture alone is not an altogether accurate index to the carbon content of steel (except when it is in the ingot form). As the appearance of the fracture can be and often is greatly modified by the manner of heating and hammering or rolling and by the temperature at which the bar was finished. A bar of steel can be worked in such a manner that several pieces can be broken from it, each exhibiting a different fracture; the decarbonized skin, however, will not be noticeably modified. Another guide for estimating the carbon content of steel will be found in forging. Notice the scales which fall from low carbon steel. They will be thick, heavy and rough. The lower the carbon the thicker the scale, and vice versa. The scales from high carbon steel will be thin, light and smooth. Another test is in hardening. Steel of 130 to 150 points carbon will harden a very low red, and when hardened at the proper heat will show a fracture nearly as smooth and fine and much harder than glass. Steel of 110 to 130 will harden a low red and show a firm, fine fracture and will require more force to break it than the steel of higher carbon. Steel of 90 to 110 carbon hardens at a medium red, will refine nicely and will be tough as well as hard. Steel of 70 to 90 carbon will harden well at a good red heat and will be exceedingly tough and strong. The lower the carbon the more heat it requires to harden the steel and the tougher it will be. The heads of cold chisels and all tools which receive

blows, if made from a good grade of steel of from 75 to 85 points carbon will batter up, spread out, and finally curl under against the body of the tool without chipping off, but if such tools are made of steel of 100 points carbon the heads will not batter up so easily and will chip off instead of curling over, and if made of 120 carbon steel they will chip off easily, and if such tools as flatters or fullers, or any tool which receives heavy blows, if made of high carbon steel, will split off in large pieces and will be liable to split in the center clear to the eye, and for this reason will not be a satisfactory tool. Steel of less than 60 points carbon will not hold an edge. Steel of less than 55 points carbon will not harden in a satisfactory manner, and if used for battering tools the heads will spread out rapidly and will continue to batter down easily.

To continue the experiment take the remainder of the eight pieces of steel and nick them on one side about an inch apart for the entire length; then heat them in such a manner as to obtain a white heat on one end up to the first nick and have a decreasing temperature toward the other end so that at the last nick the steel will be only black hot, have the heat decrease down as gradually as possible so that the steel will be at a decidedly different temperature at each nick. As soon as the desired heat is obtained quench the piece in a bath of cold water. After all the pieces are hardened in this way dry them thoroughly and break them

at each nick and arrange them in rotation, each bar separately, and put them in the case with the others. A case of fractures prepared in this way will be found to be both greatly interesting and an instruction to all steel workers. By means of such experiments there is much to be learned which cannot be put into print. By carefully inspecting such fractures you can readily see what effect different heats have on the several grades of steel. The first or hottest piece will be very coarse grained in all the different grades of steel, but will show considerable difference between the high and low carbon specimen. The second piece will be coarse grained and extremely hard. The third will be very hard but too coarse grained. The fourth piece will be very hard and the grain of the low carbon specimen will be the finest possible, but will show too coarse a grain in some of the highest carbon pieces. The fracture which shows the finest grain will be nearly as hard as the coarser ones and a great deal stronger and tougher and will be sufficiently hard to resist the best file. This is what is called the refining heat. The next piece will be hardened and refined around the outside but the interior will be soft. The next piece will not be hardened at all, and the last piece will be water annealed. If these experiments and points are carefully carried out the operator will be able to judge steel as to quality and carbon and he will know how each grade of steel looks when in its natural condition

and also how it appears when subjected to all different heats, and he will also know what amount of heat each grade of steel requires to produce the fine velvety appearance called refining, which is the required heat for all tools to be hardened at.

As previously explained, the structure of steel becomes finer grained as the carbon content increases, but any grade of steel may present a different fracture owing to the heat it was allowed to cool from after being worked and the mechanical manipulation it had been exposed to. Change of shape is more rapidly obtained by rolling than by hammering, so invariably rolled steel will present a coarser fracture than hammered steel, also small or thin bars of tool steel will present a finer fracture than bars of a larger cross section. The smaller the cross section the finer the fracture, and the larger the cross section the coarser the fracture in all steel as it comes from the mill unannealed and un-hardened. The reason for the above difference of appearances of fractures of steel of a certain carbon content is: Bars of small dimensions cool more rapidly in working, and are necessarily finished at a much lower heat than large bars. Round bars of large dimensions present the coarsest fracture of any form, and very thin flat bars the finest. Steel which has been nicked cold and broken will present a somewhat coarser fracture than it would if nicked at a cherry red heat and allowed to cool and then broken.

Steel which has been badly overheated before rolling or forging to the finished bar will be coarse grained and the particles will be brighter than in steel of normal condition. All of these points must be taken into consideration when judging steel.

We sometimes find a bar of steel which has a flaw or pipe in the center which extends the entire length of the bar. This is caused by the end of the ingot becoming hollow in cooling. This hollow portion is nearly always removed before the ingot is forged, but sometimes a portion of it escapes detection and if the man who inspects the finished bars does not detect it, a piped bar of steel will reach the consumer. Such steel will burst when hardened and should never be used for a solid tool. In bars of suitable dimensions, piped steel may be safely used for milling cutters or any article which has a hole through the center sufficiently large to entirely remove the pipe. Center flaws are sometimes caused by improper forging. In this case both ends of the bar may present a perfect fracture but the middle part of the bar may have a flaw in it several feet in length.

All steel makers will cheerfully replace all steel found to be piped or otherwise imperfect. In cutting up stock for the manufacture of any articles which must be hardened, it is advisable to carefully inspect the ends of every piece. The best way to cut stock is with a power hacksaw. In this way any interior de-

fects in the steel may be easily observed and bad results eliminated. To become a competent judge of steel requires close observation, experience, patience and careful experimenting.

ALLOY STEELS.

Alloy steels contain a percentage of carbon and various other hardening elements. Fungsen, Chromium and Manganese are among the principle ones.

These steels are more difficult to work than regular carbon steels and are more liable to be injured by heat.

When properly forged and hardened a tool made of alloy steel will cut harder material and will hold an edge when run at a higher speed than ordinary steel will stand. The author has worked considerable alloy steel of various makes, but as each brand requires different treatment, the only rule I can recommend is to follow the directions sent with the steel. Alloy steels are used for nearly all kinds of tools except those which must receive blows.

All tool steel contains a small per cent of manganese, generally 0.02 to 0.04 per cent. This small amount does exert but very little influence on the steel, but when tool steel contains a large per cent of manganese it is called manganese steel and is very strong and

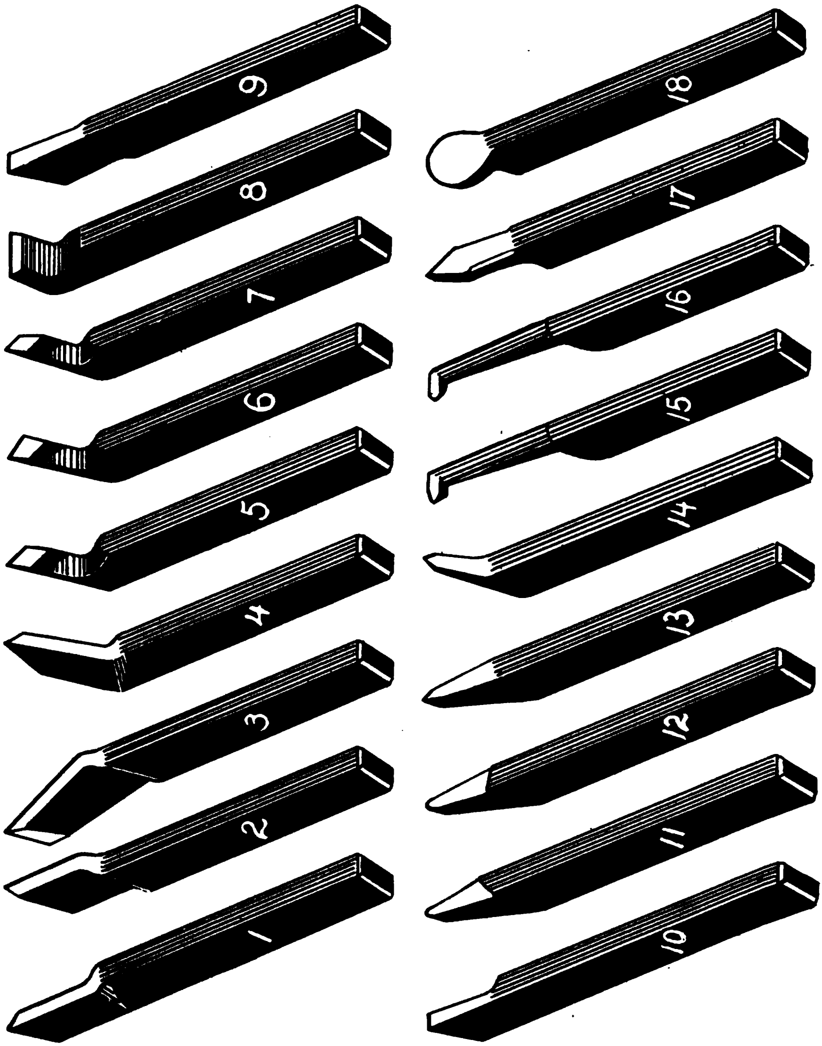
tough and of great natural hardness and is very difficult to work.

Chromium is added to steel for the purpose of increasing its hardness, but it also increases its brittleness. Tungsen also increases the hardness of steel, as well as its toughness. Both chromium and tungsen imparts to the steel a fine grain while in the un-hardened condition, and when hardened a very fine, smooth velvety grain, much finer than ordinary steel. Nickel is also added to steel and greatly increases its strength. Nickel steel is generally used for armor plate, cannon and machine parts, but is not used for cutting tools.

Table of Carbon Tempers and Temper Colors Adopted For Specific Uses.

	Temper Colors.	Points Carbon.
Anvil, faces	draw no temper	80 to 90
Arbor, all kinds	draw no temper	70 to 90
Axe, wood	dark straw	90 to 100
Axe, stone	purple to blue	75 to 85
Ball, bearings	draw no temper	100 to 120
Barrels, gun	not hardened	50 to 65
Bits, auger	purple to blue	60 to 70
Bits, jointer, and plover wood	straw	110 to 120
Bits, coal drills	pale blue	80 to 90
Bits, stone drill	straw to blue	75 to 90
Blade, knife	straw to purple	90 to 110
Bolt, heading dies	straw to purple	70 to 80
Carving, tools for wood	straw	100 to 120
Centers, lathe	straw	85 to 100
Chisels, machinist chipping	purple	85 to 95
Chisels, blacksmith's, hot	blue	75 to 80
Chisels, blacksmith's, cold	blue	75 to 80
Chisels, track work	blue	75 to 85
Chisels, stone	straw to blue	80 to 90
Chisels, wood	straw	110 to 120
Cones, for ball bearings	straw	70 to 90
Cutters, pipe	dark straw	90 to 110
Cutters, milling	light to dark straw	100 to 125
Cutters, for nail machines	straw	110 to 125
Dies, rivet and bolt heading	straw to purple	70 to 80
Dies, blanking	straw	90 to 120
Dies, cold heading	straw	100 to 110
Dies, drop forging	dark straw to purple	70 to 90
Dies, power and steam hammer	" " " "	65 to 80
Dies, nail	dark straw to purple	110 to 120
Dies, thread cutting	straw to purple	100 to 120
Dies, thread rolling	straw	120 to 150
Dies, wire drawing	very light yellow	115 to 125
Drills, twist	dark straw	110 to 125
Drills, stone	straw to blue	80 to 90
Drills, star	straw to blue	100 to 110

	Temper Colors.	Points Carbon.
Expanders, flue	dark straw	90 to 100
Files	draw no temper	100 to 130
Forks	very light blue	80 to 100
Fullers	purple	70 to 80
Flatters	purple	70 to 80
Grips, for threading machines	dark straw	80 to 90
Hammers, blacksmiths'	straw to purple	70 to 85
Hammers, machinists'	straw to purple	85 to 95
Hammers, nail	straw to purple	80 to 90
Hammers, pneumatic	straw to purple	65 to 75
Hardies	blue	70 to 75
Hob taps	straw	80 to 100
Jaws, vise	straw	80 to 90
Jaws, wire puller	straw	100 to 120
Knife, blades	straw to purple	90 to 110
Knife, shear	purple to blue	75 to 90
Links, valve	not hardened	60 to 75
Magnets	draw no temper	110 to 120
Mandrels	draw no temper	100 to 110
Mauls, bridge builders'	purple	70 to 80
Moulds	straw to blue	80 to 100
Nail, cutters	straw to blue	110 to 125
Picks, clay	blue	70 to 80
Picks, mill	draw no temper	110 to 120
Picks, stone	purple to blue	75 to 85
Picks, coal	blue	75 to 85
Pins, crank	not hardened	50 to 65
Pitching tools	purple	75 to 80
Plover tools, stone	straw to purple	75 to 80
Punches and Dies	straw to blue	85 to 110
Punches, blacksmiths'	blue	75 to 85
Quarry tools	straw to blue	70 to 85
Razors	light straw	110 to 140
Racer for ball bearings	straw	85 to 95
Rods, piston	not hardened	65 to 75
Rolls	straw to blue	80 to 100
Saws, circle	spring temper	80 to 95
Saws, hack	straw	140 to 150
Saws, band	spring temper	85 to 90
Screws, set	purple	60 to 70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	Temper Colors.	Points Carbon.
Sledges	purple	65 to 75
Snaps, rivet	purple	65 to 75
Springs	very light blue	90 to 110
Swages, saw	purple	85 to 90
Taps	straw	90 to 110
Teeth, saw	purple	80 to 90
Tools, brick mason's	straw to blue	80 to 95
Vise Jaws	straw	80 to 90
Wedges, for stone	blue	60 to 75
Wedges, wood	blue	60 to 70
Wrenches	not hardened	60 to 75
Wood working tools	straw	110 to 120

The accompanying cut represents a set of 18 lathe tools.

No. 1, right hand side tool.

No. 2, left hand side tool.

No. 3, left hand bent side tool.

No. 4, right hand bent side tool.

No. 5, straight diamond point.

No. 6, left hand diamond point.

No. 7, right hand diamond point.

No. 8, broad nosed finishing tool.

No. 9, cut-off or parting tool.

No. 10, side parting tool.

No. 11, right hand roughing tool.

No. 12, left hand roughing tool.

No. 13, straight chasing tool.

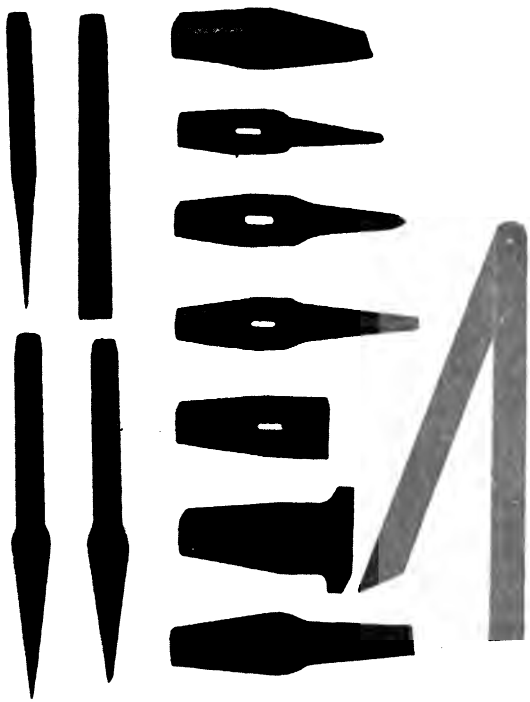
No. 14, bent chasing tool.

No. 15, inside chasing tool.

No. 16, boring tool.

No. 17, centering tool.

No. 18, round finishing tool.



FORGING TOOL STEEL.

Forging tool steel is a subject which has received very little attention. Nearly every blacksmith has had more or less experience in this line, but the men who forge tool steel as it should be done are not very plentiful. Most of them think that all that is necessary is to forge the article to the proper shape and size. They pay very little attention to the heat; so long as the steel does not fly to pieces it is all right in some smiths' estimation. However, the successful steel worker knows that such heats will do for iron and soft steel, but not for tool steel. Some smiths boast that they can forge any kind of a tool at one heat, and, to perform this disastrous stunt, they heat the steel as hot as possible without it falling to pieces, then with rapid, heavy blows with hammer and sledge the tool is smashed into the desired shape at one heat, when perhaps two or three heats would have been required to properly forge the tool. Some of these steel smashers are good mechanics and make as nice a looking tool as any one could, but they heat altogether too hot for forging and then greatly abuse the steel while on the anvil. Then, without allowing the steel to cool off, they re-heat it and harden it at a heat sufficient for forging soft steel, then they draw the temper to a nice straw color and think they have done the job up brown,

but when the tool is put to the test, it is found worthless.

Other smiths will forge a tool in good shape and without overheating it, and then when the tool is finished they will ruin it by hammering it at a black heat; some will even wet their hammer and anvil and give the tool an awful beating and boast that by this water hammering, as they call it, the steel will be greatly refined and put in a far better condition than it was before, and that the tool will be a wonderful one, but when it is hardened the chances are it will crack, and if it does not, it will never hold a good, keen edge, for the simple reason that the cold hammering has made the steel brittle and full of strains.

There is still another class of smiths who persist in forging steel at a cherry red. By so doing they make a lot of unnecessary work for themselves and helper, and when the tool is finished it will be full of strains and will be liable to crack in hardening or will break easily when in use. The cold hammering of steel might have been all right 200 years ago, when tools were made of blister steel, but the high grade tool steel, as it is now made does not require, and will not stand any such abuse without bad results. It is a well known fact that medium, or low carbon steel, can be improved by hammering. This has been proved by practical tests. Tools which must endure shocks or blows, and all tools which must undergo severe use, will give

better results if properly forged than a tool which has been machined to shape, if hardened and tempered exactly alike and made from the same bar of steel, but the opposite results are very liable to occur unless the forging is done by a practical steel worker who thoroughly understands the nature of steel and knows how to properly manipulate it. The author has had an extensive experience in forging tool steel and has often seen good steel ruined in forging by men who thought they knew it all, when in reality they knew nothing at all about working steel and were too contrary to learn.

The tool smith, no matter how skillful or wise he may be, cannot improve the very high carbon and alloy steel by hammering or any quack nostrum which may have been handed down to him from antiquity. Smiths who can forge high carbon and water hardening alloy steels and leave them in as good condition as they were in the bars are experts, and will have no trouble in working any grade of these steels as far as forging is concerned.

To properly forge tool steel we must have a good, clean fire, sufficiently deep to allow several inches of fuel under the steel, so that the blast will not strike it. Use plenty of fuel, as free from sulphur as possible, and keep the steel covered with charcoal or soft coke, so as to protect the steel from the air as much as possible. To properly heat steel for forging the fire should be large enough to insure even heating, and the blast

should be sufficient to heat the steel thoroughly and evenly, but if the blast is too strong the corners and edges will become overheated long before the heavier parts become heated through. Too strong a blast will soon burn the fuel out of the center of the fire, thus allowing the blast to strike the red hot steel, which is about the worst abuse tool steel is liable to receive, and causes the thin parts to become badly decarbonized or air burned, as the condition is sometimes called. Allowing the steel to lay in the fire and soak after it is properly heated will produce the same results, but not to so great an extent or so unevenly. The best results can only be gained by obtaining a uniform heat and not exposing the steel to the fire any longer than is necessary. For large tools or forgings which require considerable work, or where great change of form is required, the steel may safely be heated to a good yellow; then forge it quickly, but not with extra heavy blows unless it is a very large tool or forging. When the heat decreases the force of the blows should also decrease, and when the very dark red appears, hammering must cease and the article be returned to the fire and reheated. If there is considerably more work to be done on the article it may be heated nearly as hot as before, but if there is but little more work to be done upon it, heat it only a good red and proceed to finish the job. Always finish a tool at a dark red, but never hammer tool steel after the red has disappeared.

All flat tools should be finished by an even thorough hammering on the two flat sides, but do not hammer a flat tool on the edges during the finishing process, and do not use overly heavy blows in finishing a tool. Of course the force of the blows and the amount of hammering required to properly finish a tool must necessarily be governed by the size and thickness of the tool, but remember that when the red disappears it is time to stop the hammering. Steel of high carbon does not require, and will not stand, hammering at as low a heat as steel of low carbon. The directions given above are best suited for steel containing less than 90 points carbon; the hammering should cease when the heat descends to a very dark red. After the tool is properly forged it should be heated to an even red, or to about the proper heat for hardening, which is from 1300 to 1500 degrees Fahrenheit, depending upon the carbon content of the steel; when this heat is obtained the tool should be laid aside in a dry place where no wind will strike it, and allowed to cool off entirely, or, better still, place them in a box of hot lime or ashes and allow them to remain there until cold, which will remove all strains caused by forging. Then they should be ground before hardening.

If steel is heated too rapidly the outer portion will become soft and be in good condition for forging, while the interior will not be more than red hot. Now, if steel is forged in this condition, the outer parts will

yield readily to the hammer, while the harder interior portion will not; and the outer part will be torn loose from the center or enormous strains will be set up, which will cause the article to spring or crack when hardened. An even heat for forging is of the greatest importance and cannot be too carefully attended to. Uneven heating is the cause of more trouble than over heating. Both are bad, but of the two, uneven heating is the worst and most commonly met with.

It is generally supposed that it ruins steel to upset it. However, it can be done without any noticeable detriment to the steel. The writer has often upset steel to make broad nosed tools and also upset the ends of parting tools when dressing tools which had been worn or ground too thin on the end. To do this heat the tool to a good bright red and upset it somewhat larger than the required size and forge it down to the desired shape and no bad results will follow; but if the end of the tool was only upset to the required finished size and no forging done on it after the upsetting, the corners would be liable to crack off and the tool would not hold as good an edge as it would if it had been forged as directed above. I do not claim that upseting is helpful to steel, but if properly done it will do but little, if any, harm.

The ordinary blacksmith's forge will do for heating ordinary tools or forgings, but better results can be obtained if the steel is heated in a suitable furnace,

and for large and expensive tools and forgings the furnace is indispensible, for large pieces of steel cannot be heated in a forge fire without the corners and edges being exposed to more heat than is necessary, and to secure an even thorough heat the steel would have to be turned over several times, and consequently the corners and edges would be heated and then partially cooled several times before center reached the desired heat. The result of such heating is the thin parts will be decarbonized and the corners will be liable to crack off when the article is hardened, but if the steel had been heated in a furnace the heat would have been far more uniform and without overheating the thin portions. Where there is much steel to be heated for any purpose a suitable furnace should be provided. Tool steel should always be forged on a smooth anvil or hammer dies. Forging tool steel on a rough, uneven, battered up anvil or dies, and with hammers or sledges with rough or broken edge cannot be too strongly condemned. Forging with rough tools not only produces a bad looking job, but causes the surface of the article to be full of strains, which will manifest themselves when the article is hardened or when in use.

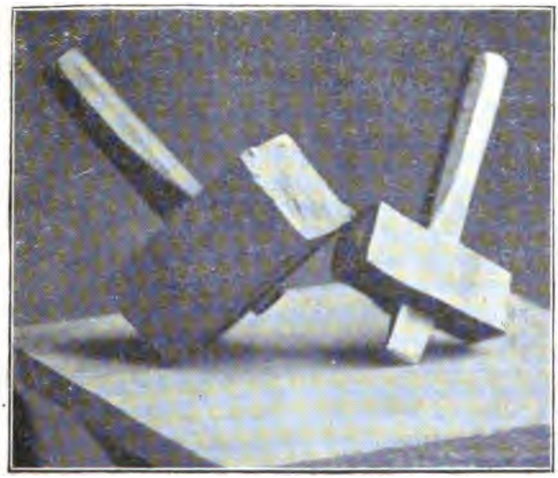
Forging tool steel with a steam hammer can produce excellent or disastrous results. When a square piece of steel is to be forged into a round form many smiths simply knock down the corners, which changes the square to an octagon, then they roll the steel under

the hammer until it is something like round. Such treatment may burst the steel internally and cause serious trouble. The proper way to forge a piece of square steel into the round form is to first octagon, then 16 corner. After this is done it may be rolled carefully, using light, quick blows. When a piece of steel is to be greatly reduced in size it is generally customary to pinch it down an inch or so at a time with the corners of hammer dies. This method of forging will do for soft steel, but should not be employed on tool steel, for tools made of steel which have been pinched and smashed into shape will never give satisfactory results unless the steel is thoroughly annealed after forging, and even then the tools will not be as good as they would have been if the steel had been properly forged. When forging steel, even heating, even hammering, and smooth faced tools with no sharp or rough edges are of the utmost importance and in no case should be overlooked.

If the foregoing directions and precautions are heeded, a great deal of unsatisfactory results will be avoided. There is more science in forging tool steel than is generally anticipated.

FORGING COLD CHISELS.

If a smith understands the scientific principle of forging steel he can make a good cold chisel every time, providing he has good steel to make it from.



This cut represents two thin flat cold chisels made from ordinary 7/8 octagon steel. One of them was driven through a cold bar of 1 3/8 square steel; the other was driven through a cold bar of 2 1/4 square iron. These chisels were made by the author and were driven through the bars of steel and iron with a steam ham-

mer in the blacksmith shop of the Youngstown Iron, Steel Sheet and Tube Company, on the 16th day of November, 1903, for the purpose of demonstrating what tool steel can be made to do when properly worked.

A smith who has not got this knowledge may once in a while make a good chisel, but he does not know why that chisel is any better than the others; and no doubt if he should make a dozen more from the same bar of steel he could not get another as good as that one. I have seen this happen to lots of men who were supposed to be good steel workers. Cold chisels should be made of a good grade of steel containing from 75 to 90 points carbon.

To make a cold chisel, first cut off enough steel to make it the desired length. Heat it to a bright red back about three inches, then trim off the corners on two parallel sides so that the end will have a short, blunt point; this will keep the edges from lapping over in forging. Draw the chisel on the horn of the anvil the first heat. This will draw it much faster and will not spread it out sideways as much as drawing on the face of the anvil. Consequently it will not require as much hammering on the edges to get it into the proper shape. The less you hammer a chisel on the edge the better it will be. When you have hammered the chisel on the sides until it is a dark red, never turn it up edgeways and strike it; but if it must be hammered on the

edge put it back in the fire and heat it again; then do all the hammering on the edge that you are going to do. Then hammer it evenly and thoroughly on the sides, but do not strike the edges again. When you get the chisel nearly to size and shape, medium heavy blows are necessary to close the pores and pack the steel. This should be done when the steel is a dark red, but when the red disappears stop hammering immediately. Put the chisel in the fire, but do not turn on any blast. As soon as it is a dark red take it out and give it several good blows on each side, then heat again and hammer as before. Repeat the operation three or four times, but remember to keep your hammer off the edges. If the chisel gets too wide or the edges get crooked you can file it or grind it to shape.

If you wish to make a flat chisel out of three-quarter inch steel draw it out so that it will be about one-eighth of an inch thick at the end, and about one-fourth of an inch thick three inches from the end. A chisel of this size should be about seven-eighths or three-quarters of an inch wide and a trifle thicker in the center than it is at the edges.

When you have the chisel forged let it cool off, then grind it. When the chisel is ready to harden, heat it to an even dark red back as far as it has been drawn. Plunge it in the bath straight down as far as you have it hot enough to harden; move it up and down a little, but not sideways. As soon as the chisel is cooled

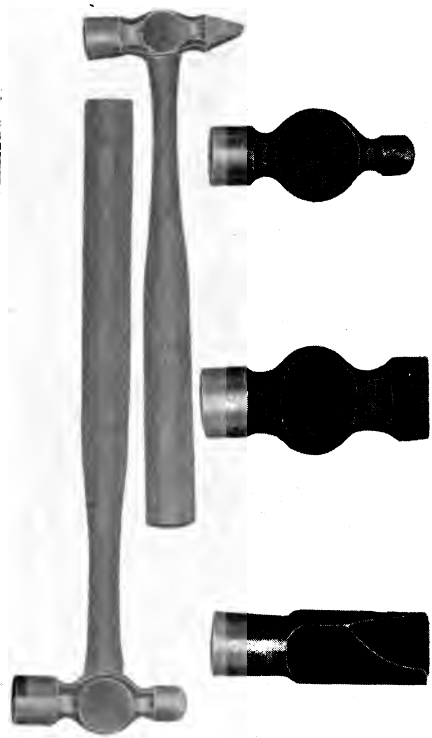
through take it out and rub one side bright (of course we have only enough heat left in this chisel to start the temper a little; that is all we want); now hold it over the fire and draw it evenly all over alike to a regular cold chisel blue.

A chisel made in this way can be worn back three inches before it needs dressing, and the edge will stand far better than the ordinary chisel. One chisel made in this way will last longer than three dozen chisels made like a blunt wedge and hardened about one-fourth of an inch on the end, as is generally done. This way of forging steel holds good on all flat tools and tools that can be finished on the flat sides, such as side tools, flat drills, cut-off tools, scrapers, mill picks, stone tools, etc. Remember to finish on the flat sides and keep off the edge and finish at a dark red. And never hammer steel after the red heat has disappeared.

Nearly 5 years ago I dressed a flat cold chisel for George R. Hasbrouck, No. 122 North Diamond street, Ravenna, Ohio, a machinist employed by the John F. Buyers Machine Company. He has used that chisel almost 5 years, and during that time it has not been in the fire. Over two inches have been worn off the cutting end, and about the same amount pounded off the other end.

This chisel was drawn out long and thin. Was not over one-fourth of an inch thick four inches back from the end, and was hardened and tempered back

about five inches; was seven-eighths of an inch wide, nine inches long, and less than one-eighth of an inch thick at the point, and not over three-sixteenths of an inch thick three and one-half inches from the point. This chisel is still in use and will last for several months more. It has been used on all kinds of iron and steel that a man ever cuts with a cold chisel. Mr. Hasbrouck is a first-class machinist and knows how to grind and use a chisel, which are two things that a great many machinists do not know. If any of my readers doubt what I say about this chisel, they will please write to Mr. Hasbrouck and see what he has to say about it.



FORGING HAMMERS.

The above cut represents five hammers which were forged and finished by the author. There was no machine work done on these hammers. They were forged, then annealed, after which they were finished by filing, then hardened and tempered according to directions given in this book. These hammers have been in use over four years, during which time they have never been dressed and they have neither chipped nor battered. The ball paen hammer at the left was forged from 1½ inch square steel, is 2½ inches wide through the eye, weight 2¼ pounds. The next is a straight pean, weight 3¼ pounds, is 2⅝ wide in the eye, was forged from 1¾ inch square steel. The one at the right is a diagonal pean, was forged from 1½ inch steel, weight 3 pounds. It may appear very odd to some, but it is a very handy hammer, and for many jobs is the best shaped hammer ever made. The cross peaned riveting hammer was forged from 1 inch square steel, weight ¾ pound. The other ball peaned hammer was forged from 1¼ inch square steel, weight 1¼ pounds.

A good hand-made hammer is something that every blacksmith and machinist is proud of. Hammers should be made of a good grade of steel containing about eighty points carbon. To forge a hammer, heat the steel evenly to a bright red or dark yellow heat

and punch the eye first; then fuller it all around on both sides of the eye. Use a small fuller first and leave stock enough in the middle to allow for working the eye to proper size. The eye should be punched with a small punch made expressly for that purpose; it should be tapering and about twice as wide as it is thick; the edges should be rounding. The punch should be about three-eighths wide by one-fourth of an inch thick at the small end, and about one inch wide by one-half inch thick at the large end, and about five inches long. The next thing to be done is to spread the eye. This should be done at a bright, red heat with a fuller and set hammer. After spreading the steel at the eye, fuller it a little all around again; draw the ends down to the desired size, then fuller it again with a larger fuller. The eye should be worked on both sides, and the tapering drift or punch should be driven in from each side so as to finish the eye larger at each end than it is in the middle. If the eye should be made the same size all the way through, the hammer will not stay on the handle nearly as well as it will if the eye is smaller in the middle. When you have the hammer finished to size and shape, heat it to an even, bright red; stand it on end and strike it on top; one good blow will be sufficient; do not strike it hard enough to knock it out of shape. The fullering and punching the eye causes strains in the steel; the blow on the end will

relieve the strains. After this is done the hammer should be thoroughly annealed.

You have all seen hammers that were cracked or broken at the eye, or one end broken off. The reason of this is, the man who made the hammer did not relieve the strains. After the hammer is annealed it should be finished up by turning and filing, then hardened and tempered to a dark straw color. A hammer should be tempered so that a good, fine file will cut it a little. It is better to have a hammer a little too soft than too hard. Never temper a hammer hard enough to mark the anvil, for hammers are easier to dress than anvils.

Sledges should be hardened and tempered the same as hammers. Flatters, fullers and all anvil tools should be struck on the end to relieve strains caused by forging, then thoroughly annealed. Never fuller a flatter or swage below the eye, and do not draw the heads of battering tools too small. If these directions are followed you will not be troubled with tools breaking.

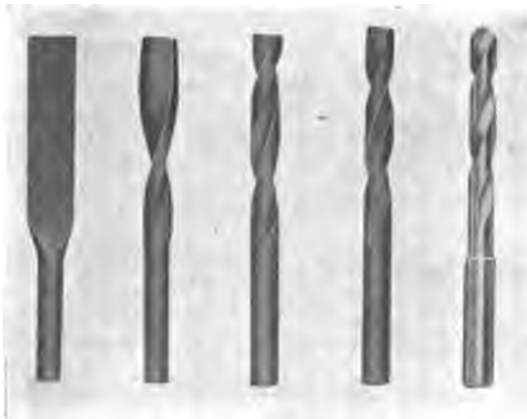
I have found it to be a good idea to harden the heads of battering tools. To do this, heat the head to a dark red and harden; then draw the temper to a very pale blue.

Some smiths are always having trouble with their hot and cold cutters, which either break or bend; some will crack in hardening. These difficulties can be over-

come by following the directions given for making cold chisels.

FORGING A COLD CUTTER.

A cold cutter should be made of a good grade of steel containing about seventy-five points of carbon. Leave them heavy enough to stand the work they are intended to do. Cold cutters should be forged and hardened the same as hand cold chisels, but should be tempered a trifle softer. If you follow these directions you will be able to make a cold cutter which will cut off at least a thousand pieces of seven-eighths inch octagon tool steel without being dressed; or cut from thirty to fifty large steel rails in two without being dressed. I have seen over a dozen chisels go to pieces on cutting one steel rail, but they were none of my make. Remember the secret of making good chisels lies in the hammering and heating, but not in the hardening bath. Chisels and cutters of all kinds can be successfully hardened in water.



FORGING TWIST DRILLS.

The above cut shows how a twist drill is forged from start to finish.

This is something you do not see done every day. To make a one-half inch straight shank drill, take a piece of one-half inch round steel; flatten three or four inches of it; do not stretch the steel endways; just flatten it to about one-eighth of an inch thick; do not strike it on the edges only enough to keep it straight;

let it spread just as wide as it will. Be sure to have it the same thickness back as far as it has been flatened. Then heat it a bright red; stand it up edgeways on the anvil; take a light hammer, begin at the back end of the flattened portion and strike it on the left hand corner, or, in other words, strike it on top; only reach over to the left enough to catch the corner. Keep working toward the point with quick, light blows; when you get to the point turn the drill over and begin at the back end as before.

You will see you have knocked it a little in a twist all the way along, and have upset the edges the entire length. That is just what we want. Keep right on as long as it is red hot; then heat it again and hammer the same as before. It will look more like a twist drill every time you strike it. If you work fast you can forge a nice drill in about five or six heats; when done forging, carefully anneal it, then file out the flutes with a round file and finish the edges and sides with a fine flat file. Harden it the entire length of the twist and draw the temper to a straw color. Any skilful smith can, with a little practice, make a nice drill.

An excellent reamer can be made in the same way, only forge the twist in the opposite way (left hand). Make the reamer tapering instead of straight, and file the clearance in the same way as a twist drill. This will make a good right hand reamer.

I have made a great many twist drills and have often been called a liar for saying I made them, because the man I was talking to had never seen a good hand-made twist drill. Whenever a man tells me he does not believe I made the drill, I always offer to put up twenty-five dollars or more that I can make another one just as good in his presence. That always settles the matter in short order.

FORGING A BUTCHER KNIFE.

Steel for knife blades should contain about one hundred points of carbon.

To make a butcher knife you should have a piece of seven-eights by one-eighth inch steel. Cut off enough to make the knife the desired length; heat it to a dark red and bend it a little edgeways; then draw the inside edge. It will straighten in drawing. When drawing the edge, commence at one end and work to the other, then turn it over and work as before. Be careful not to over-heat the steel, and hammer as much on one side as you do on the other; do not hammer after the red has disappeared. Draw the knife as thin as you want it and trim the point to the desired shape, as shown in cut. If you hammer more on one side than the other, the knife will be liable to spring in hardening. When you are ready to harden the knife, heat it edge down, in a clean fire, using very little, if any, blast; heat it evenly the entire length to a dark red. Only heat the blade hot enough to harden about one-half its width; then plunge it in the bath edge down. Any bath may be used—oil of most any kind will do. By only hardening the front half of the blade you will leave the back tough and strong. Knives hardened in this way cannot easily be broken.

If knife blades are hardened in water, draw the

temper to a purple; but if hardened in oil or grease draw the temper to a straw color.

Woodworking tools should be made out of good steel containing about one hundred and ten points of carbon, and carefully forged according to directions given for forging cold chisels. This method holds good on all flat tools, no matter what they are intended to cut. Woodwork tools should be hardened and drawn to a straw color.

Every shop needs a good steel worker, but lots of them have to get along with poor tools because they cannot get a man who understands working steel. This is one reason why there is so much self-hardening steel used, simply because they could not get their tools dressed so they would do the work. If a tool, made of carbon steel, is properly forged, hardened and tempered it will cut harder material than any self-hardening steel.

Self-hardening steel is not a success for turning chilled rolls. A tool made of a good grade of steel and properly hardened is far better. For roughing sanded castings, and for work that runs at a high speed, the self-hardening tool is the best, but not for a finishing tool.

MAKING MACHINE TOOLS OF COMMON IRON.

A lathe or planer can be made of common iron that will cut the hardest kind of material. To do this, forge the iron tool and grind it; then take a piece of thin cast iron; heat the tool almost to a welding heat; also heat the cast iron to a melting heat. Rub the melting cast iron over the end of the tool; it will unite to the wrought iron; get enough of the cast iron onto the tool to form a heavy plate on the cutting edge and plunge it into cold salt water; draw no temper. This will make a tool that will cut glass or anything else except a diamond. You cannot make a mark on it with the best file in the world. I have made tools in this way that cut chilled castings that self-hardening tools would not begin to cut.

Tools made in this way will not wear very long because the cast iron plate is thin. It is the cast iron that does the cutting.

DRESSING ANVILS.

This is a job which most smiths are afraid of, but is not as great an undertaking as some imagine it to be. If the anvil is not too large it can be easily handled by two short bars properly fitted into the holes in the anvil made for that purpose. The easiest and best way to dress an anvil is to anneal it and have the face planed, then harden it properly and the anvil will be as good as new. If you cannot get the face planed it can be dressed hot, then when cold it should be filed or ground smooth before hardening. Build a large deep fire; heat the anvil nearly all over; if you heat only the face it will be very liable to loosen the steel face and ruin the anvil. When you get it to an even bright red take it out and upset the edges, then smooth it up all over the face with a large flatter. When heating be careful not to overheat the corners.

FORGING, HARDENING AND TEMPERING SPRINGS.

Making springs is a job that the majority of smiths are not very familiar with, and a job that requires care and skill. For all small forged springs use tool steel of about eighty or ninety points carbon. Small springs should be forged heavy enough to allow the springs to be filed smooth before hardening.

When forging springs be very careful not to overheat the steel, and do not hammer it after the red has disappeared; and do not hammer on the edge any more than is actually necessary. When you heat a spring to harden it be very careful to get an even heat, but do not heat it any hotter than is necessary to produce the desired results.

Do not attempt to heat a very small or thin spring in an open fire. If you have nothing but an ordinary forge with which to heat the spring, take a piece of pipe of suitable size and plug up one end air tight; place it in the fire and cover it over with coke; leave the open end project out a few inches, then heat the spring inside of the pipe.

The above method of heating is not as good as a furnace, but is a great improvement over heating in an open fire.

Very thin springs harden nicely by heating red hot and plunging into a cake of common yellow soap; if

too stiff, draw the temper a little. All kinds of springs harden nicely in oil; melted tallow gives good results. After a spring is hardened in oil or grease it is necessary to draw the temper. To do this, hold the spring over the fire until the oil burns off; then try the spring; if it is too stiff, dip it into the oil again, taking it out instantly and proceed as before. For some grades of steel it may be necessary to burn the oil off three or four times to obtain the desired elasticity. Some kinds of springs give good results when hardened in boiling water and the temper drawn to a blue; this is all right with some kinds of steel, but will not do for all kinds. Springs can be successfully hardened in salt water or any bath used for hardening tools. Heat the spring to a dark cherry red and plunge it edgeways, straight down in the bath. This will make the spring very hard.

To temper springs, harden in this way: You should have a box or barrel, partly covered, so as to make it as dark inside as possible. Then heat the spring slowly and evenly until you can see the first trace of dark red when the spring is held in the dark; then allow it to cool in the air. If properly done this makes an excellent spring. I believe it to be the best method of hardening and tempering trap springs.

Another very good way to harden and temper trap springs, made of tool steel, is to heat them to a very dark red, and harden in water at about one hundred

degrees F. If this makes the spring too stiff, draw the temper by dipping the spring in oil and burning it off as described before. If you have several springs to temper, fasten them together and hang them in a kettle of melted tallow; place the kettle over the fire and boil until the tallow commences to blaze, then remove the springs and allow them to cool in the air.

Good springs cannot be expected if the steel is overheated in forging and hardening. All light springs should be made of tool steel; large springs should be made of spring steel. Springs made of spring steel should be hardened in oil or tallow and tempered by burning off the oil or tallow as described before. Spring steel contains considerable carbon and will not stand high heats. It will harden at a low red.

When forging all kinds of springs be very careful not to over-heat the steel; hammer it thoroughly all over on both flat sides when the steel is a dark red, but do not hammer after the red has disappeared; and do not hammer on the edge after you have commenced to pack the steel. Round springs should be hardened and tempered the same as flat ones.

Small coiled springs that are made of drawn wire and coiled cold, will not require hardening or tempering.

Nearly all small coiled springs are coiled cold and made of drawn steel, up to and including one-fourth inch wire. Occasionally larger sizes are coiled cold.

Springs which are coiled hot will require hardening and tempering, and should be done by heating the springs to a cherry red and plunging in cold oil; then burn off the oil over the fire, or boil the springs in melted tallow as described before.

Brass springs cannot be hardened by heating and cooling in a bath. Copper and brass is tempered by rolling or drawing cold, and annealed by heating red hot and cooling in water or brine.

FORGING SELF-HARDENING STEEL.

There are a great many makes of self-hardening steel in use. All of them are difficult to forge, but it can be successfully done by heating it slowly and evenly clear through and back some distance further than the forging is to extend. If the tool is to be forged with a steam hammer it is a good idea to heat the tool slightly the entire length, which will keep it from breaking from the concussions of the blows. Self-hardening steel will stand a higher heat than most smiths think it will, providing it is heated evenly and slowly. When the proper heat is obtained, forge the tool with quick, hard blows, but as soon as the heat descends to a dark red, stop hammering and reheat if necessary. There is not much to be said on the subject of forging self-hardening steel. All the instructions and precautions previously mentioned should be closely followed and great care used to get the proper heat, which can be determined by a careful test of each variety of steel. Complicated shapes can be forged from self-hardening steel if care and good judgment is used. Bending large sizes to right angles can only be done successfully with a steam hammer, press, or forging machine. The main factor in forging self-hardening steel is to get the proper heat and then not hammer at too low a heat.

FORGING HIGH SPEED STEELS.

High speed steel is easily forged and will safely stand a good heat. Many makes of this peculiar steel will stand as much heat as machinery steel. Most smiths will not heat high speed steel hot enough for forging or hardening. When forging this kind of steel do not be afraid to heat it up to a good bright yellow. Give it about all the heat it will stand without melting. The proper heat can be easily determined by a test. When the right heat is obtained forge it quickly, but when the heat is reduced to a red, stop hammering and reheat. Forging at a low heat will ruin high speed steel. Many makes of high speed steel can be successfully welded to iron or soft steel by using welding compound No. 9, thus saving a great deal of steel when making large tools. I have forged nearly all kind of high speed steel and with good results invariably, and if the above precautions are used there need be no unsatisfactory forging of high speed steel.

WELDING STEEL.

This is a subject in which every blacksmith has had more or less experience. We all know that some grades of steel can be welded and others cannot. The more carbon steel contains the more difficult it is to weld. Steel which contains over one hundred and forty points of carbon will not weld in a satisfactory manner. To successfully weld steel it is necessary to have a good, clean fire, as free from sulphur as possible. For welding on the anvil a short lap gives the best results. If you are troubled with the steel slipping back, take a blunt chisel and cut a notch in both pieces close to the back end of the scarf; when you take the pieces out to weld place the two chisel cuts together; this will prevent slipping. If you wish to make a "V" or split weld, notch the pieces that go inside and hammer the laps down over it. For welding flat thin pieces of steel some smiths split both pieces. If you wish to do this, split both pieces before you scarf them. Then when you scarf the ends let the inside corners of the scarfs spread as much as they will; then when you put them together the inside corners of the scarfed ends will reach onto the solid steel and will insure a good weld and leave the center strong and solid. The above is the best way of welding flat springs. After the weld is made, forge the steel to the desired shape, but leave it a little thicker than

the finished size; then finish it to the proper thickness with a flatter and sledge; give it several good blows on both flat sides while the steel is a dark red, but do not hammer on the edges after you have commenced to pack the steel.

To weld tool or spring steel it is necessary to use a flux to keep the steel form burning. Borax is generally used for this purpose. Borax always contains sulphur and sulphur is injurious to steel. If you have nothing but borax you can greatly improve it by melting it and boiling it dry. It will then be what is called charred borax and will be found to give far better results than borax in its natural state. Any of the following welding compounds will give far better results than borax on all kinds of steel.

The first is an excellent compound. I have used it several years and on all kinds of work with splendid results.

Welding Compound No. 1.

Pulverized Borax	1 lb.
Carbonate of Iron	2 oz.
Black Oxide of Manganese	3 oz.

Mix thoroughly and use as borax, only heat the steel a little hotter.

Welding Compound No. 2.

Pulverized Borax	1 lb.

Nitrate of Potash--------------------1 oz.
Carbonate of Iron-------------------2 oz.
Use as borax.

Welding Compound No. 3.

Clean Sand---------------------------5 lb.
Powdered Sulphate of Iron-----------3 oz.
Black Oxide of Manganses------------3 oz.
Table Salt--------------------------4 oz.

This compound gives splendid results on open hearth and Bessemer steel, but is not intended for tool steel. Use as borax.

Welding Compound No. 4.

Borax ----------------------------------1 lb.
Salt Peter---------------------------2 oz.
Powdered Charcoal-----------------1/4 oz.
Use as borax.

Welding Compound No. 5.

Charred Borax-----------------------1 oz.
Soft Steel or Wrought Iron Filings----1 oz.
Rosin ------------------------------1 oz.
Sal-Ammoniac ---------------------2 oz.
Carbonate of Iron-------------------2 oz.
Use as borax.

Welding Compound No. 6.

Borax	1 lb.
Dry Venetian Red	4 oz.
Black Oxide of Manganese	2 oz.

Use as borax.

Welding Compound No. 7.

Borax	1 lb.
Fine Wrought Iron Drillings	1 lb.
Clean Welding Sand	1 lb.
Carbonate of Iron	3 oz.

Mix thoroughly. Use on both sides of the scarf.

Welding Compound No. 8.

Pulverized Glass	1 lb.
Pulverized borax	1 lb.

Use as borax.

Welding Compound No. 9.

Charred Borax	1 lb.
Carbonate of Iron	3 oz.

Use as borax.

Compounds Nos. 1, 5 and 9 are excellent for welding tool steel and restoring burned steel. To test them take an old file, heat the end till it flies to pieces, then dip the end in the compound and let it remain four or

five seconds; then, with quick, light blows weld up the end, draw it out and make a cold chisel of it. You will be surprised at the results. Overheated steel will never be as good as it was before being overheated. But accidents will happen to the best of us sometimes, and it is well to know how to make the best of them. All of these compounds are first-class and are not expensive, are easily made and far better than borax for all classes of work.

We often see a smith take a dozen heats on a weld and then not get a solid job. Some are afraid to heat the steel hot enough, others heat it too hot. Some will plaster both sides all over with borax and then try to stick them together with both scarfs swimming with melted borax. The chances are it will slip and he will take another heat. After awhile he may succeed in sticking them together, but it will not be a solid weld.

If you use borax give the pieces a couple of good blows, over the anvil, to knock all the borax off the scarfs before putting them together to weld. We often hear smiths say, "there is nothing as good as borax for welding steel," but most smiths know better. Any of the welding compounds given in this work will give better results than borax, but borax is better than nothing for welding. There are several good welding compounds on the market which are patented, but for welding tool or spring steel compound No. 1 is the best I have ever used. All the compounds and solu-

tions in this book are good and have been thoroughly tested. You need not be afraid to try any of them. If you follow directions you will be pleased with the results.

When welding steel do not be afraid to use a little elbow grease. A few good, quick, hard blows are worth a hundred light ones; if you cannot strike a blow that will do some good, do not strike at all; just stand and look at it.

Large tools are often made of soft steel and have a tool steel face welded on. This makes a good tool if properly done. To do this, first forge the soft steel to the desired shape, then heat it to a bright red and lay the cold tool steel in position and take a good welding heat on the two together. By first heating the soft steel to a bright red you will be able to get a good welding heat on both pieces without burning the tool steel. When ready to weld commence at one end or one side and work to the other; weld it solid all over the first heat if possible. The high heat necessary to weld is an injury to the tool steel, and unless a good welding compound is used the steel will show the effects of the high heat.

When welding tool steel to iron or soft steel always get a good, high heat on the iron or soft steel and as high a heat on the tool steel as it will stand without injury. Then commence welding on one side and work to the other, or commence in the middle and work both

ways; never strike one side and then the other, for if you do the dross cannot get out, which will prevent solid welding. In some cases a poor weld may cost someone their life. Let your motto be a solid weld or none at all.

If you wish to weld a very small piece to a large one, take a good welding heat on the large piece and only a red heat on the small one; put them together and use the hammer smartly and the weld will be as good as if both pieces had been at a welding heat. I have often welded very small pieces onto large ones by taking a good welding heat on the large piece and not putting the small one in the fire at all. The heat from the large piece will put a welding heat on the small piece in a very few seconds.

When welding steel be careful to get a good, clean heat and do not use too much borax or welding compound. If you use borax be careful to knock off all melted borax from the scarfs before putting them together to weld. Some welding compounds give the best results if left on the scarfs, others should be knocked off the same as borax.

ANNEALING TOOL STEEL.

The definition of the word annealing is to soften by heating and cooling slowly. The object of annealing steel is to make it soft enough to work easily, and to remove internal strains which always exist in steel that has not been annealed properly, which is the result of hammering or rolling. If these internal strains are not removed before the article is hardened, the chances are that it will spring or crack in hardening. Internal strains are the cause of steel springing or cracking, and great care should be used to guard against strains in steel that is to be hardened. Uneven heating, uneven hammering and uneven cooling are the chief causes of internal strains.

To anneal a piece of steel we heat it red hot and cool it slowly; the longer it is cooling the softer it will be.

Steel may be annealed by several different methods, but in all cases it must be heated red hot and slowly cooled. In most shops a box of air slaked lime or wood ashes is used to cool the steel in. Either of these answers the purpose nicely, providing the box is large enough and its contents kept perfectly dry. A good way is to heat a large piece of iron and put it in the lime and let it remain there while the steel is heating; then when the steel is red hot take the iron out and put the steel in the same place and cover it about six inches

deep with the lime or ashes. In this way the lime or ashes will be hot and perfectly dry and good results will be sure to follow. In some shops they use a box of charred leather. If leather is used it is necessary to have a box with a good, tight fitting cover and keep it closed as much as possible.

It is positively necessary to heat steel slowly and evenly for annealing and every other purpose. Lime, ashes or charred leather will be found to be a satisfactory means of annealing if the above directions are followed.

A very good method of annealing which I have used many times, with good results, is as follows: Take a piece of soft pine board an inch thick and large enough to hold the pieces to be annealed; make a hole in the middle of the lime, place the board in the bottom of it; then when the steel is hot enough put it on the board and lay another board the same size on top of the steel and cover up with lime or ashes; the pieces of board will smolder and keep the steel hot a long time. The process of cooling will be very slow and the results satisfactory.

When steel must be annealed and cannot be allowed time enough to cool in lime, fairly good results may be had by placing the hot steel between two pieces of soft pine board and allow it to cool without burying in anything.

In annealing steel never heat it any hotter than

you would to harden, and in hardening never heat any hotter than is necessary to produce the desired results. Also, be careful to heat the steel slowly and evenly all through; for steel that is annealed at an uneven heat is very apt to spring or crack when it is hardened. There is ten times as much steel ruined by overheating and uneven heating as there is by all other causes combined. A man to be a successful steel worker must understand the nature of steel and keep his mind and his eyes on his work.

Another way of annealing is to pack the steel in iron boxes, using charcoal for packing material. Put about one inch of pulverized charcoal in the bottom of the box, then put in a layer of the articles to be annealed, but do not let them come within about one-half inch of each other or within one inch of the box, fill in between the pieces with charcoal and cover them about one inch deep; then put in another layer of the steel and so on until the box is filled. If you do not have enough steel to fill the box, fill it up with charcoal; put on the cover and seal it lightly with fire clay, then the box is ready to put in the furnace. As a means of being able to know when the contents of the box are heated clear through, you should have several small holes drilled in the lid of the box near the center; run a small rod of steel or iron in each hole long enough to reach the bottom of the box and project above the cover about two inches.

When the box has had time enough to become red hot clear through pull out one of the little rods; if it is red hot all over you will know the steel is also, but if the rod is not hot enough wait awhile and pull out another rod, and so on until the proper heat is reached, then put out the fire and let the work cool down with the furnace, or the box can be removed from the furnace and buried in lime or ashes; this is safer than leaving the box to cool in the furnace. If you leave the box in the furnace, watch it carefully and be sure that the walls of the furnace are not hot enough to cause the steel to become overheated. If the furnace is too hot you should leave the door open a while or take the box out until the furnace gets cooled down some; then put the box back, close the door and let the work cool with the furnace, which will be very slow, and the work will be satisfactory.

Charcoal and charred leather contains carbon and will help to keep steel from becoming decarbonized. Heating steel weakens it and lowers the percentage or carbon on the surface unless something is used that will restore carbon to steel. Bone should never be used for annealing or hardening valuable tools, because bone contains considerable phosphorous which is very injurious to steel and is the worst impurity steel ever contains.

All tools that are liable to spring or crack in hardening should be roughed out within about one-

eighth of an inch of the finished size, then thoroughly annealed again. If it is a tool that has a hole in it the hole or holes should be made but a little smaller than the finished size; then after annealing the second time the holes can be bored out to size and the job finished up.

The object of annealing after the job is roughed out and holes made is to relieve all strains and to allow the steel to expand and contract under nearly the same shape as it will when hardened. If this second annealing is properly done it will do away with a great deal of springing and cracking in hardening. If the piece springs in annealing do not straighten it cold; if it is not large enough to finish without straightening, heat it red hot and straighten it. If steel is hammered cold it will be sure to spring or crack when hardened. Machinists and tool makers often hammer steel cold, and then when it is hardened it springs and the man that hardened it gets the blame.

I have had lots of trouble in this way. Some machinists and toolmakers know about as much about steel and it proper treatment as a hog knows about Sunday school. All they know is to get the job machined to size and shape regardless of how many strains they cause and how many square corners they put on the job. Square corners always invite cracks. If an article cracks or springs in hardening the blame is always laid on the man that

hardened it, or else on the steel, and perhaps the hardener gets discharged on the grounds that he does not understand working steel. I was once discharged in this very same way. They hired a new man, he met the same fate. They kept right on hiring and discharging until the men in charge came to their senses and fixed the blame where it belonged.

To be a successful steel worker you must study the nature of steel and know what it is liable to do under different conditions and how to avoid undesirable results, no matter whether it belongs to your department or not.

In heating steel never let it come in contact with cast iron, for cast iron will extract carbon from the steel when them are both at a red heat. Never keep steel red hot any longer than necessary; never blame the steel for bad results caused by your own carelessness or the ignorance of the man that machined the job.

Water annealing has some advantages over all other methods but it also has its disadvantages. It will not remove strains and for general work cannot be recommended, although it has many advocates. Steel which has been properly water annealed will file nicer than steel annealed by other methods, and will also take a far finer finish when machined. Water annealing gives a texture to steel which is very different from steel annealed in lime or ashes. Water an-

nealed steel will, when machined, present a white appearance, and if a lubricant is used a smooth, clean thread can be chased, which is difficult to do with steel annealed in the regular way.

To water anneal a piece of steel, heat it evenly to a cherry red and allow it to cool in the air until it will no longer char a pine stick, then cool it in soapy water. Another way to determine the proper heat for quenching is to hold the steel in a dark place until all traces of red disappears, then plunge it in water, oil or soap suds. When water annealing has been effected at precisely the right heat, the steel will scale off in places and will present a spotted appearance. This method of annealing often comes in good play when the steel must be had for immediate use.

ANNEALING HIGH SPEED AND AIR HARDENING STEEL.

High speed steel can be annealed as soft as any other tool steel providing the proper treatment is employed. There are very few men outside of those who work in the steel mills that know how to anneal the so-called high speed and self-hardening steels, and it cannot be done by simply heating the steel and putting it in lime or ashes. It must be heated very evenly and slowly to a dark red and kept at that heat several hours, then cooled extremely slow and excluded from the air while being heated and cooled. The best way to anneal high speed and air hardening steel is to pack it with charcoal in an airtight box, heat box and all. Keep it red hot three or four hours, then close the furnace tightly and allow the steel to cool down with the furnace as slowly as possible. When properly done the steel will be very soft and easily machined. If the furnace is not suitable to allow the box to cool slowly, the box may be removed and placed in a large box of lime or ashes and left there for at least 24 hours, then it may be taken out and the steel removed.

ANNEALING SELF-HARDENING STEEL.

Self-hardening steel can be annealed soft enough to machine fairly well by heating it to an even medium red and maintaining the heat three or four hours, then burying the steel in a large air-tight box of saw dust. Pine saw dust gives the best results, but do not use dust from seasoned wood for it will burn too rapidly, in any case the saw dust should be fresh and made from green wood, when pine is used. Fairly good results can be obtained when dry hardwood saw dust is used. Be sure to have a large box and pack the saw dust around the steel and close the box tightly.

HARDENING BATHS.

To successfully harden all kinds and shapes of tools as well as various other articles made of tool steel, it is necessary to use baths of various compositions, and of various degrees of temperature. In order to obtain the best results, an extremely cold bath should never be used, except for very large, heavy articles, which have no teeth or thin projections. The hardness of steel is determined by the rapidity of the quenching (or cooling process) consequently, a bath that will cool a piece of steel quickly will make it harder than a bath which would require more time to absorb the heat. Mercury will absorb heat with more rapidity than any other known hardening bath; but it is very expensive and is not used extensively for the purpose of hardening steel. Any bath which causes steel to become extremely hard also causes it to be very brittle. Brittleness of steel is always an undesirable feature, and to eliminate this conditions baths, which will impart a certain degree of toughness as well as sufficient hardness are the most desirable and practical for general use.

Steel which has been rapidly cooled in addition to becoming very hard and brittle, will also be liable to crack from internal strains caused by the surface becoming hard and inflexible while the interior is still hot and undergoing changes of structure and size. A

bath of clear water gives good results on most tools, providing it is not soapy or dirty. A bath of salt water, or brine, is extensively used with good results on nearly all cutting tools. The temperature of the bath should be from 50° to 70° F. for general work.

A good bath can be made by adding three pounds of salt to one gallon of soft water; there should be several gallons of the bath for small work and a barrel or more for large work. If the bath is small and there is several pieces to harden it will soon become too hot to properly harden the steel. There is no danger of getting the bath too large; the larger the better; the benefit gained by having a large bath is, it will remain at the proper temperature. If steel is heated uniformly and hardened in a bath of uniform temperature then all the pieces will be of the same degree of hardness; this is a very important point which cannot be gained if the bath is too small. There are a great many hardening solutions in use which give better results than clear water or salt water. I have thoroughly tested the following baths and know them to be better than water or brine:

Hardening Solution No. 1.

Corrosive Sublimate	3 oz.
Salt	6 lbs.
Soft Water	4 gal.

This solution is poison, so be careful.

Hardening Solution No. 2.

Sal-Ammoniac	6 oz.
Corrosive Sublimate	3 oz.
Soft Water	4 gal.

This is also poison, but is an excellent bath for all kinds of cutting tools. Draw the temper to the desired degree of hardness.

Hardening Solution No. 3.

Blue Vitrol	4 oz.
Prussiate of Potash	4 lbs.
Salt	6 lbs.

Dissolve one gallon of warm water, then add four gallons of raw linseed oil and one-half pound pulverized charcoal. This is an excellent bath for thin tools that must be hard and tough. If too hard, draw the temper.

Hardening Solution No. 4.

Saltpeter	1 lb.
Prussiate of Potash	3 lbs.
Citric Acid	2 lbs.
Carbonate of Iron	2 lbs.
Salt	50 lbs.
Soft Water	30 gals.

The above is one of the very best solutions in use.

Hardening Compound No. 1.

Carbonate of Soda	1 oz.
Carbonate of Potash	1 oz.
Cyanide of Potash	1 oz.

To be pulverized thoroughly and mixed together. Heat the tool to a dark red, dip the cutting edge in the compound, return to the fire a few seconds then plunge in salt water or any of the before-mentioned solutions. This will make a tool hard enough to cut glass, chilled cast iron or anything else except a diamond. Draw no temper after using this compound.

Hardening Compound No. 2.

Salt	2 lbs.
Saltpeter	½ lb.
Alum	½ lb.
Salts of Tartar	¼ oz.
Cyanide of Potash	1 oz.
Carbonate of Ammonia	6 oz.

Pulverize thoroughly and mix together; keep dry. This compound is intended for hardening tools made of cast iron. Heat tool to a good red; sprinkle thoroughly with the compound and plunge in hardening bath. Draw no temper.

Oil baths of different kinds are used to accomplish various results. Tallow or lard makes a very good bath for hardening knife blades, springs and all thin articles which must be tough. Raw linseed oil makes

an excellent bath for thin tools which require a hard edge. A bath of boiling water works nicely for hardening springs and for some makes of steel gives a better result than any other bath, but sperm oil or lard oil is generally used for hardening springs.

When a bath of clear water is used the tank should be supplied with an overflow and supply pipe, so that fresh water can occasionally be put in, otherwise it would become stagnant. When any of the hardening solutions are used the tank should have a neat fitting lid which should be kept closed as much as possible so as to keep out dirt and also to keep the contents from evaporating. Many steel workers have a pet hardening solution which they use for any and all classes of work and claim that this magic solution of theirs will impart all sorts of wonderful good qualities to the tools hardened in it. There are men who make a living by selling a receipt for making a hardening solution, and a preparation for restoring burnt steel, and strange as it may seem, they find smiths who are foolish enough to buy their "hocus pocus" quack nostrums. These grafters are men who understand heating and working steel and for this cause alone they are able to produce a good tool and their game is to make their victim believe that the secret of successful hardening lies in their quack solution or compound.

One of these professional swindlers entered a shop in Pittsburg, Pa., a few years ago and proceeded

to try to convince a friend of the author that he had a wonderful method of hardening steel. It consisted of a two quart bucket, the contents of which in every way resembled ordinary crude petroleum. After carefully forging a tool he cooled it off in his magic solution, he then heated the tool and hardened it in clear water. After drawing the temper the tool was put to the test and proved to be first class in every way. Mr. Grafter happened to be very hungry and excused himself for a few minutes and went out to get a lunch. During his absence my friend emptied his little tin bucket and filled it from a barrel of crude oil which he had in the shop. When Mr. Grafter came back he was asked to treat another tool, which he did in the same manner with equally good results. It is needless to say that he did not sell any receipts in that shop. Some sort of a bath is an absolute necessity when hardening carbon steels, but a great deal more depends upon proper heating than on the composition of the bath, and no bath can give steel the desired hardness and toughness unless the steel is quenched at the proper heat.

HEATING STEEL FOR HARDENING.

There are several methods employed for heating steel which give good results, viz: the muffle gas furnace, the lead bath, the cyanide or cyanide and salt bath. The pack hardening process and the natural draught coke furnace are the most extensively and successfully used. Every shop where tools are hardened should be equipped with one or more of the above named furnaces, but it is a lamentable fact that they are not to be found in over one-half of the shops in which they are needed every day.

In many shops where there is considerable steel to be hardened we find no furnaces of any description. The tool smith must heat milling cutters, taps, dies, reamers and everything else in an ordinary blacksmith's forge and then get called down if the tools do not prove satisfactory in every respect. The forge will do very well for heating small tools such as cold chisels, lathe sharpener and planer tools, providing care is used to have a good clean fire of sufficient depth and size to insure even heating and protection from the blast. In many shops where there is a large amount of steel to be hardened and annealed, and where the equipment for heating should be the very best, we find only a small, ill contrived, home-made furnace, natural gas, hard coal or coke being used as a fuel. Tools heated in this sort of a furnace are ex-

posed to the products of combustion and also to the air, and consequently cannot be as good as they would have been if the heating had been done in an up-to-date manner. Such furnaces will do for annealing or forging purposes but are not satisfactory for heating valuable tools for hardening. The writer knows of several large manufacturing companies which have every department of their plant (except the blacksmith shop) equipped with all the latest and best tools and machinery that money can buy. Some of these so-called modern plants have no blacksmith shop, but have the forges and hardening furnaces stuck in one corner or end of some department, which could not be used for any other purpose, or if they have a blacksmith shop, it is a small, low, insignificant affair which will allow its occupants to freeze in winter and roast in summer, and equipped with old fashioned forges, battered up anvils and possibly an old steam hammer with the dies worn out and the housing broken and bolted together, and a small coke furnace without a smoke stack stuck in one corner close to a big door and with a large window on each side. With this good for nothing outfit the blacksmiths and steel workers are expected to turn out as much and as good work as if they had modern tools and appliances to work with. The tool dresser's forge and hardening furnace should always be located where the light will be as uniform as possible and entirely excluded from

direct sunlight, for every variation in the light will cause a variation in the heat given the steel (unless the heat is gauged by a pyrometer). It is impossible for a man to detect the proper heat when the light is too bright, and especially so when the direct rays of the sun strike the heated steel or the operator's eyes. If there are windows near the hardening furnace or tool forge, they should be painted or curtained. Too much light or variations of light is one of the chief causes of a great deal of improper heating.

THE MUFFLE FURNACE.

A mufflle or oven furnace constructed to burn gas is a satisfactory means of heating steel. These furnaces are made in a large variety of sizes and shapes. It is advisable to procure a furnace which is especially adapted to the class of work to be done. This method of heating protects the steel from the products of combustion and also from air, and consequently there is very little danger of decarbonization or oxidation of the surface of the steel. With any furnace burning gas as fuel it is an easy matter to adjust the blast and gas valves so that a uniform heat can be obtained and maintained for hours at a time, providing the gas pressure is uniform, which is an important and desirable feature, and is very difficult to obtain with a furnace which burns coal or coke. A muffle gas furnace equipped with a pyrometer is the ideal appliance for heating steel, and by its use precisely the right heat can be obtained and satisfactory results will follow. Variation in gas or blast pressure will cause a variation in the heat and must be taken into consideration.

THE LEAD HARDENING FURNACE.

Red hot lead furnishes a very satisfactory, economical and speedy means of heating small and medium sized tools and parts of machinery which require hardening.

To obtain the best results, gas should be used for fuel, although gasoline or fuel oil may be used with excellent results. Also a lead furnace can be constructed to burn charcoal, coke or hard coal, and if particular attention and precautions are used in regulating the fire, good results can be obtained.

The main advantages of heating in lead are that several pieces can be heated at a time and there is but little danger of overheating or uneven heating if proper precautions are used. The lead should be occasionally stirred up from the bottom to equalize the heat as the bottom will in a short time become hotter than the top.

The surface of the lead should be kept covered with small pieces of charcoal, which will burn and help to keep the lead at an even heat. The charcoal also prevents oxidation or the forming of dross to a great extent, but some drops will form and should occasionally be skimmed off to prevent it sticking to the steel.

The lead used for heating steel should be as pure as possible.

HEATING IN LEAD.

Steel will float on melted lead and must be turned over occasionally, and just before removing from the lead the article should be held beneath the surface for a few seconds to insure an even heat.

Small articles of an even thickness may be put into the lead without being partially heated, but generally speaking it is advisable to heat the steel somewhat before it is put into the lead, and articles of irregular shape having projections or thick and thin portions should be heated nearly red hot before putting them into the lead.

If a milling cutter or any article of irregular shape should be plunged into red hot lead without first being heated through, the chances are that the sudden expansion of the teeth or thin portions would cause cracks between them and the heavy portions of the article which would require considerable more time to heat and expand, or if the article did not crack in heating, enormous strains would be set up as a result of the thin portions becoming red hot while the heavy parts were still in an unyielding condition.

Then, when hardened, the article would be very liable to crack as a result of the strains, but this difficulty will be entirely overcome if these precautions are used.

Lead has a tendency to stick to the steel in places

and if not removed before the steel enters the hardening bath, soft spots will be formed, because the portions covered with lead will not come in direct contact with the cooling fluid and will not harden. If the lead sticks to the steel it should be removed by means of a wire brush. To prevent the lead sticking to the steel, use a strong solution of salt and water. A better solution can be made by dissolving 1½ pounds of cyanide of potash in a gallon of boiling water, when the solution is cold it is ready for use.

Dip the tools in the solution and put them before a fire or in some hot place where they will dry quickly but do not put them in the lead until perfectly dry, for the least bit of dampness will cause the lead to fly. Some hardeners use a paste made of salt, two lbs., and wheat flour 1½ lbs., mix together and add sufficient warm water to make it about the consistency of varnish.

This paste is to be applied with a brush. Fill in between the teeth and all sharp corners. The article must then be thoroughly (but slowly) dried. This paste is recommended for all articles having fine teeth, such as taps, dies, files, etc.

The best way to prevent lead sticking to the steel is the following: Melt together 1 lb. cyanide and 1 lb. salt, allow it to cool. When cold break it up and place enough of the mixture on the lead to cover the surface, and add a little more every hour so as to keep

the lead covered. As the articles pass into the lead they will become coated with the mixture, and again when they are removed. Articles hardened in this way will be bright and clean, lead will never stick to them. This method does away with the trouble of applying a solution or paste to the steel and then waiting for it to dry, and also prevents the forming of dross to some extent.

When it is desirable to harden only part of an article, it can be held in a pair of tongs so that only the parts desired hard will be heated. The article should be moved up and down a little so as to prevent a sharp dividing line between the hot and cold portions, which would cause strains, cracks or warping when hardened. The lead should be kept at the proper red heat. Some hardeners heat the lead entirely too hot, then leave the article in the lead just long enough to heat the surface to the proper heat, then harden it. This is a very objectionable method because it does not heat the steel uniformly. The thin portions will become too hot long before the thicker portions are sufficiently heated, and when the article is quenched it will be very liable to crack or spring as results of the uneven heat.

If the lead gets too hot it may be cooled down to the proper temperature by putting in a large piece of cold iron or steel for a minute or two.

For heating all long, slender tools, such as ream-

ers, drills, broaches, mandrels, arbors, etc., red hot lead or cyanide is the most satisfactory method the writer has ever used. With either of these methods the tools are held in a vertical position which prevents the tendency to spring of their own weight while hot. When heating such tools be sure to keep the lead stirred up so as to insure an even heat the entire length and do not move the tools sideways when in the heating or hardening bath.

Reamers and drills are not generally hardened only as far as they are fluted, and should be raised and lowered slightly while heating so as to do away with the sharp dividing line between the hard and soft portions which is almost sure to be the source of trouble if allowed to form.

HEATING STEEL IN CYANIDE OF POTASSIUM.

This method of heating is very similar to heating in lead and has some decided advantages not found in the lead method. Steel sinks in melted cyanide, but floats on red hot lead, and the cyanide will not stick to the steel and would do no harm if it did, for it would come off instantly when the steel was plunged in the hardening bath.

This method can be successfully used in nearly all classes of hardening and is especially recommended for heating dies which are intended for transferring impressions such as dies for making coins and similar purposes, also dies with engraved surfaces. Small articles should be suspended in the molten cyanide by means of a wire basket. In this way a large number of pieces may be heated at a time, large pieces should be suspended in the cyanide with wires which should be hooked over the edge of the crucible, which will prevent the steel laying on the bottom. When ready to harden the articles can be removed by means of the wire and plunged in the hardening bath, but do not use galvanized wire for the hooks or basket.

The effect of cyanide is to cause the steel to have a harder surface than it would have if heated by any other method except pack hardening, and consequently tools thus heated will give good results.

Another effect of the cyanide is to cause the steel

to harden on the surface at a temperature below the proper hardening heat, and if particular attention is not paid to this fact the steel may only receive a thin surface hardening, and the portions just beneath the surface will be soft. To avoid this undesirable result be sure to heat the steel sufficiently to produce refining but no hotter.

When the articles to be hardened are nicely polished and perfectly clean, nice colors will show after hardening. To produce nice mottled and vine like colors the steel should be removed from the cyanide and passed through a fine spray and into a tank of clear water as quickly as possible. Colors cannot be produced when salt water or other hardening solutions are used. Articles thus hardened can be drawn to any desired temper and still retain the colors by heating them in oil and allowing them to cool in the oil down to about 300° F., then they may be removed and wiped clean and allowed to cool in the air.

The fumes of melted cyanide are very poisonous and the cyanide furnaces should have a hood and stack similar to a forge, or some other means should be provided for disposing of the fumes.

Equally good results can be obtained by using salt and cyanide, equal parts.

THE PACK HARDENING PROCESS.

Pack hardening consists of packing the articles to be hardened in iron boxes with carboneous material in precisely the same manner as for case hardening or annealing. See directions for packing.

The material used for pack hardening differs from that used for case hardening and annealing; but the boxes and test rods and also the methods of packing are the same. For pack hardening use granulated charred leather and granulated charcoal, equal parts, or charred leather alone may may be used when extra hardness is desired.

When packing small articles place them in rows and attach a piece of wire to each article and allow the wire to extend up to the top of the box. Place the articles and wires in such a position that the articles may be readily lifted out in rotation. When the articles are long it is advisable to use a box of such shape as will allow the articles to be packed and heated in a vertical or standing position. In this way they will not be nearly so apt to spring as they would if heated in a horizontal position, but if such boxes cannot be had or if the furnace will not accommodate such boxes it will be necessary to heat them in a horizontal position. In this case use plenty of packing material and tamp it in as solid as possible and place all flat articles on edge.

When the packing is completed and the cover placed in position and thoroughly luted with fire clay the box or boxes are ready to be placed in the furnace. Heat them slowly to an even dark red and allow them to remain at that heat for sufficient time to become evenly heated clear through, when the desired heat is reached. The work should then be kept at that heat for from one to four hours according to the size of the articles and the degree of hardness desired. The larger the articles the longer they should be kept red hot. For large milling cutters with heavy teeth, four hours will be required. For small cutters with thin teeth two hours will be enough.

When treating steel by this method do not heat it quite as hot as would be necessary with other methods, as steel thus treated will harden in a satisfactory manner at a lower heat than the same steel heated by any other means, except cyanide bath.

When the heating is completed remove the work from the furnace, open the box and plunge the articles one at a time in a bath of raw linseed oil. If the articles are slender move them up and down in the bath but do not swing them sideways, but if the articles are of such shape that they will not be liable to spring, they should be worked around in all directions as rapidly as possible so as to insure even hardening. If the articles are not moved around in the oil,

vapor will quickly form around the steel and hardening will not be satisfactorily done.

The oil bath should be large and deep and some means of keeping the oil from becoming too hot should be provided. This may be accomplished by pumping the oil from near the surface through a coil of pipe covered with cold water and forcing it back into the oil tank at the side or bottom. For hardening articles which have a hole in them it is desirable to have the walls of the hole thoroughly hardened, it is necessary to have the return pipe so located that the oil can be forced through the hole. This is especially necessary when hardening such tools as blanking dies, hollow guages, etc.

The superiority of this method of heating over all others is that steel when thus heated will harden in oil at fully as low if not a lower temperature than would otherwise be required to harden it in water. Steel when hardened in oil will not crack and is not nearly so liable to spring as when water is used. Articles which are very difficult to harden in the ordinary way can be hardened by this method in a very satisfactory manner and cutting tools can be run at a higher speed and will do a great deal more work than tools hardened by other means.

The writer has used this method on a large variety of work and especially recommends it for all sorts of milling cutters, taps, dies, reamers, guages, etc.

Pack hardening is also a very economical means when large numbers of articles are to be hardened as several boxes of work may be heated at a time. Also a low carbon steel can be used if hardened by this process when it would be necessary to use a much higher carbon steel if the hardening was to be done in the ordinary way. However, it is not advisable to use a steel of less than 100 points, 1 per cent carbon, for machine tools.

When the pack hardening process is used cutting tools will not need to have the temper drawn as low as when other methods are used. Always have all tools as hard as they will stand and always harden at the lowest possible heat at which the steel will refine thoroughly.

THE COKE FURNACE.

A furnace burning coke as fuel can be made of the muffle type which will give good results providing care is used in regulating the fire. A coke furnace should have a good smoke stack with a damper in it so the fire can be kept under perfect control. The muffle or oven can be made of cast iron and of dimensions to suit the class of work to be done. The muffle should be above the fire and placed so that the heat will pass up both sides and over the top to the smoke stack.

The muffle should be cast in one piece and should be at least one inch thick, and if the muffle is large it should have ribs cast on its outer surface to prevent warping. The muffle should be provided with a neat fitting door so as to exclude the air. The door should have a two inch hole in it covered with mica so the heat can be observed without opening the door.

Coke furnaces of this type will necessrily have to have a damper in the door of the ash chamber to admit the air to form the draught, and should also have a damper in the fire box door, and by means of these dampers and the one in the stack the heat can be controlled nicely. When using this kind of a furnace it will be necessary to turn over large pieces while heating, so as to secure an even heat. For the bottom of the muffle will be somewhat hotter than the sides

and top. If care is used this sort of a furnace will give good results and will burn hard coal equally as well as coke. Connections with a blast is not necessary as the stack will furnish all the draught required.

There are a great many coke furnaces used for heating steel which have no muffle. In this case the articles to be heated are laid on an iron plate or placed in a furnace on the coke. When this sort of a furnace is used there should be about six inches of fire space, that is the fore plate should be about six inches above the grate. The top of the fire should be covered with small pieces of coke. The grates should have half inch openings and should not be allowed to become clogged up.

When care is used good results can be obtained from this sort of a furnace. It is a rapid and cheap means of heating.

WHY STEEL HARDENS.

Why does steel harden is a question which has been often asked but the answer to the question has never been satisfactorily proven. This question has been the source of much controversy and scientific research. It is a well known fact that steel which contains carbon to the amount of 60 points or more will harden when heated red hot and suddenly cooled in a hardening bath or clear water, but why it hardens is somewhat of a mystery.

Without a doubt the hardening of steel is brought about by the molicular changes caused by heating and sudden cooling. The most rational theory as to why steel hardens is as follows:

When steel containing carbon is allowed to cool slowly from the melting temperature or when the steel has been annealed or forged and allowed to cool in the air from the forging temperature, the carbon forms a net like combination with the steel. When the steel is heated to a cherry red the carbon is absorbed uniformly by the steel, and if quickly cooled the carbon becomes fixed in this condition and the effect is the steel is hardened, but if instead of being quenched the steel is slowly cooled, the carbon gradually separates from the molicules of the steel and re-assembles to its original net-like form, which is more complete after the steel has been annealed than when simply allowed to cool from a red heat, which accounts for the softness of annealed steel.

HARDENING STEEL.

The hardening of steel has very appropriately been termed the "Crowning process."

The art of hardening steel is one of the most useful as well as complicated branches of mechanical arts and is a most delicate and important branch of steel working.

To become a successful hardener requires great care and patience, also perseverance, good judgment, and knowledge concerning the nature of steel and its peculiarities. It is not exactly necessary for the hardener to be a metallurgist or a chemist, but a fair knowledge of the fundamental principles would be of great service to him.

Generally speaking the men engaged in the hardening of steel are apt to entertain an opinion that they are experts in the art and that there is nothing more for them to learn. They are apt to boast that they have served an apprenticeship and ought to understand their business, and for the simple reason that they ought to know something they expect their employers and fellow workmen to consider them an authority on steel and all methods of working it.

Again we find men who are always boasting of the number of years they have worked steel. They seem to think that because they have been allowed to

exist and hold a position as tool smith or hardener for several years they must certainly be experts.

As a general rule these would-be experts possess but very little real knowledge, but instead they have plenty of wind and manage to bluff their way through.

To this class of men I have nothing to say, for they are too far advanced to learn anything. It would be impossible to convince them and folly to attempt to teach, but for the benefit of those who wish to improve their opportunities and better their conditions I will endeavor to explain the art of hardening steel to the best of my ability and to point out the causes of bad results and how to avoid them, also to show how the best results can be obtained.

Nearly everyone knows that steel is hardened by heating and sudden cooling, the methods employed in heating and baths used for cooling have previously been considered. We will now proceed with the hardening process. Some tools and articles can be heated and plunged into the water or other hardening bath and entirely cooled off. When they are removed from the bath they are ready for use. Articles which can be thus treated are small balls for bearings, some forms of bushings, machine tools for working brass and cast iron, mill picks, some forms of stone cutter's tools, roll turner's tools, scribers and scrapers, also files are generally hardened by the above methods. The majority of tools and hardened articles require

tempering after hardening. The tempering process will be considered later on.

Great care is required for heating steel for hardening. To obtain good results we must heat the steel evenly to the proper hardening or refining heat, then get it into the hardening bath as soon as possible. Never allow steel to remain in the furnace or fire after the desired heat is obtained. Allowing steel to remain exposed to heat and the action of the air after the proper heat is obtained is one of the chief causes of bad results. Cutting tools thus exposed will not hold a good edge. First class steel is often injured and condemned as inferior or worthless when in reality the fault was in the treatment it received.

All long, slender articles should be heated in a vertical position, if possible, which will eliminate the tendency to spring or bend of their own weight. If such articles must be heated in a horizontal position they should be turned over occasionally while heating so as to insure an even heat and lessen the liability to spring.

When the desired heat is obtained the article must be plunged into hardening bath in a vertical position and moved up and down in the bath; but not moved to and fro, until they become nearly cold. If long or slender articles are immersed in a slanting position they will invariably spring and in many cases will be so crooked that they will have to be heated and

straightened. Moving them to and fro in the bath will produce the same results.

Taps, reamers, drills, mandrels, arbors, and long shear knives are the principal articles of this class. There are some articles which must be immersed at a slanting position or else slightly curved before hardening in order to have them straight when hardened. This class of articles are half round reamers, bevel edged shear knives, and all long articles which have a light and heavy side, also flat articles that have holes in them which are counter sunk on one side.

All articles which are liable to crack or spring in hardening should be left in the hardening bath only a few seconds, just long enough to insure sufficient hardening of the working or cutting parts. Then quickly remove and plunge into oil or boiling water, which will eliminate all chance of cracking. If long, slender articles are hardened by this method they will not be nearly so liable to spring, and if they do they can be straightened by heating them to about 300° F. At this heat they will be sufficiently flexible to permit straightening with but very little danger of breaking.

The cause of cracking is strains, and strains are caused by uneven forging, uneven heating and uneven cooling. Annealing if properly done removes all strains that may exist in the steel, but when the steel is hardened enormous strains are caused by the sudden cooling and contraction of the surface and sharp

corners, edges, teeth, etc. The above mentioned parts become hard and unyielding while the heavier and interior portions are still hot and changing in volume. If such articles are left in the hardening bath until cold they will be liable to crack through the middle or the thin parts may break loose from the heavy portion. When this class of work is dipped in the hardening bath for a few seconds and then plunged into boiling water or oil, the contraction is retarded and the heat remaining in the heavy portions is partially transmitted to the hardened portions and cooling is accomplished slowly and evenly and there will be no cracks.

After the steel has had ample time to cool down clear through to the temperature of the oil or water it may be removed and allowed to finish cooling in the air, but should not be put into cool water after being removed from the oil or boiling water. When oil is used it should never be allowed to become hot, for if oil becomes hot it will not absorb the heat fast enough to keep the hardened portions from becoming too hot. When the oil can be kept cool it works nicely and satisfactory results will be sure to follow. Any kind of oil will answer this purpose. The boiling water method is really the safest as it is impossible to get water hotter than 212° F. The hardened steel is greatly toughened but not noticeably softened by this temperature.

The author has used the above methods exten-

sively on a large variety of work with invariable success and has hardened hundreds of articles in a satisfactory manner which could not be hardened in a cold bath without cracking. Tools treated by the above method will hold a good edge and will be very strong and durable, but remember steel must be heated evenly and hot enough to produce sufficient hardness, and no hotter. At this heat steel will refine to the utmost and will be tough and strong as well as very hard.

There can be nothing gained by going above this heat. Every degree of heat given steel in excess of the proper refining temperature weakens the steel and makes it coarser in structure and puts it in a poorer condition to hold an edge or give good results of any kind.

HARDENING MACHINE TOOLS.

The hardening and tempering of ordinary machine shop tools such as lathe, planer, shaper and slotter tools is a simple process and is generally accomplished at a single heat. The proper way to harden this class of tools is to heat them evenly to the proper refining heat, being careful to keep the cutting portions of the tool from becoming too hot. Keep this portion on top most of the time and do not allow the thin parts to become red hot sooner than the heavier portion if possible to avoid it. Allow the heat to extend back an inch or two farther than you intend to harden the tool. When the proper heat is obtained dip the tool in the hardening bath somewhat farther than you desire it to be hardened. Move the tool up and down in the bath a little, also move it around so as to cool it properly and not leave any sharp dividing line between the hardened and soft portion.

When the portion desired hard is thoroughly cooled remove it from the bath and rub one side bright so the colors can be observed. The heat remaining in the tool will reheat the hardened portions to some extent and colors of various shades will appear on the brightened surface. If the tool has been hardened at the proper heat the colors will indicate the hardness as well as the amount of heat the hardened steel is receiving. Allow the color to run down to the de-

sired tint or shade. If there is not sufficient heat in the tool to produce the desired color hold it over the fire a few seconds.

As soon as the proper color is obtained cool the tool off entirely and it is ready for use. The proper temper colors for all tools are given elsewhere in this book.

I will now mention a few of the wrong methods which are very often applied to this class of tools by men who should know better as well as by the inexperienced. The tool is thrust into the center of the fire with the cutting portion down. The blast is then turned on about six times as strong as it should be. The tool quickly becomes overheated on the corners and thin edges and before it has been in the fire a minute it is ruined. It is then dipped in a bath and held still at one certain depth until the point or cutting edge is cooled. It is then removed from the bath and rubbed up and the temper drawn to some sort of a color, but no matter what color it is drawn to it cannot be a good tool. The effects of overheating and uneven heating has previously been explained, and holding a tool in a fixed position while hardening has two very undesirable effects. First, steam will form around the article and keep the bath from acting directly on the hot steel and will thus prevent proper hardening. Second, there is a sharp dividing line formed between the hard and soft parts which is

always the weakest part of the tool. Tools thus hardened will either crack, break or bend at this line if subjected to heavy work, but men who harden tools in this manner are always ready with an abundant supply of imaginary explanations or excuses as to why the tool did not prove satisfactory. He generally lays the blame on the steel or on the hardening bath. There is one thing certain he will never admit that he was in any way to blame for the bad results, and in nine cases out of ten such men will not believe they were in the wrong when confronted by the strongest proof (which is the broken tool). The fracture tells its own story and plainly shows what sort of treatment the tool had been subjected to.

For this class of tools clear water or most any kind of a bath will give good results. The main factors are even and proper heats and proper cooling. Always leave the tool as hard as it will stand, and for hardening never heat steel hotter than is actually necessary to produce refining; also be sure to obtain an even heat and you will be a successful hardener.

HARDENING TAPS, DIES, REAMERS, SHEAR KNIVES, AND ALL TOOLS WHICH ARE COOLED OFF ENTIRELY AND THEN TEMPERED AT A SEPARATE HEAT.

When hardening this class of tools be sure to get an even heat just hot enough to produce refining and no hotter. Plunge the articles in the bath and move them around. To insure proper hardening, if there is no danger of the articles cracking or springing they may be left in the hardening bath until entirely cooled off, but if there is danger of cracking, remove them from the bath as soon as the working portions are hardened properly and immerse them in oil or hot water as previously described. Mill picks and roll turner's tools should be cooled off entirely in the hardening bath.

Stone cutter's and driller's tools should be hardened and tempered by the same method as machine tools. The temper must vary to suit the class of work. Granite tools must have a strong heavy point and should be tempered to a straw color. Limestone tools should be thinner and tempered to a purple. Sandstone tools give best results when drawn quite thin and tempered to a dark purple or blue.

If you should accidentally let an article get too hot lay it out and allow it to cool in the air until per-

fectly cold, then heat again to the proper red and harden. Do not lay it out until it cools down to the proper hardening heat and then quench, for if you do the steel is left in a worse condition than it would have been if quenched when first removed from the fire. I have often seen men lay overheated steel out until it cooled down to the proper heat, then harden it, but it should never be done. By laying the overheated article out and allowing it to cool in the air it will contract slowly; then when it is reheated and hardened at the proper heat the steel will refine and will be nearly as good as it ever was. That is if it was only slightly overheated; of course, if it was heated to a welding heat it will not refine unless it is thoroughly hammered; and if badly overheated it will never be anywhere near as good as it was before. Never let anyone make you believe that any compound or solution will make burned steel as good as it ever was before it was overheated or burned. Accidents will happen to the best of us, and it is well to know how to make the best of them.

HARDENING MILLING CUTTERS

or tools of irregular shape which are liable to crack. A very good way is to take a dish and put in just enough water to cover the tool. The teeth will harden quickly and the water will soon become hot so as to do away with the danger of cracking. I have used this method with good results. A still better way is to dip the tool in the hardening bath a few seconds, just long enough to harden the teeth or cutting surface; then take it out and immediately plunge it into oil and leave it there until cold. I have hardened all kinds of thin and irregular shaped tools in this way with satisfactory results. In some shops they use a bath of oil and water. Of course the water will go to the bottom; then when the tool is dipped it will pass through the oil first then into the water. This works nicely on some kinds of tools, but the best and safest way is to dip them in the water first and then in the oil as described above.

TO HARDEN THE WALLS OF A HOLE WHICH DO NOT GO CLEAR THROUGH.

To harden a piece of steel that has a deep hole in it, and it is desired to have the walls of the hole hardened the entire depth, it is necessary to force water to the bottom of the hole until the piece is entirely cold. To do this, get a piece of pipe about half the size of the hole; place it in the hole and dip both into the hardening bath; as soon as the article is under water commence forcing water through the pipe and do not stop until the article is cold. The pipe should go to within one-half inch of the bottom of the hole, and should be kept as near in the center as possible so that the water will come up all around alike. In hardening steel the amount of heat necessary varies with steels of different make and steels of different percentages of carbon. To accomplish different results the steel makers put other hardening elements into steel besides carbon. The lowest heat at which a piece of steel will harden in a satisfactory manner is called the refining heat. When a piece of steel is hardened at this heat, if you break it you will see the grain is very fine and the steel will be very hard and strong. Heating steel red hot and cooling it quickly not only makes it hard, but also makes it brittle, and the higher the heat the more brittle the steel will be.

TEMPERING STEEL.

When I commenced this work I intended to have a colored tempering chart in it but gave it up because I found it to be impossible to get the correct tints produced on paper, so will give a written description of temper colors and the number of degrees of heat necessary to produce each color, and the proper colors for all kinds of tools. The following is a correct table of temper colors:

Color Tempering Chart.

Light Straw	Color	---430	degrees.
Full Straw	"	---460	"
Very Dark Straw	"	---490	"
Light Purple	"	---530	"
Dark Purple	"	---550	"
Blue	"	---610	"
Pale Blue or Green	"	---630	"

Lathe and planer tools for brass, draw no color at all; for cast iron, very light straw; machine steel, steel castings, tool steel and wrought iron machine tools should be draw to a medium straw color; mill picks, scribers and scrapers, draw no color at all; just heat the tool to about 400 degrees so as to relieve strains, but not hot enough to draw the slightest color; taps, very light straw; dies, dark straw; reamers, full straw; twist drills, full straw; milling cutters, from a

light to a very dark straw; slotter tools, purple or blue; knurling tools, purple; shear knives, from a dark straw to blue; cold chisels, blue; screw drivers, let the blue run clear out; wood work tools, straw color; granite tools, light straw; marble tools, straw; limestone tools, purple; sandstone tools, blue; clay picks, blue; hamwers and sledges, from a straw to a purple.

Remember that colors do not indicate how hard a tool is, only under the right kind of circumstances. Colors simply indicate the amount of heat there is in the steel, nothing more or less. We can draw any color on a soft piece of iron or even on a piece of tin. In drawing colors there are several things that must be taken into consideration—the quality of the steel, the nature and temperature of the bath, and the heat the steel was hardened at.

When you harden a piece of steel be sure you get it hard so that a good, fine file will not take hold of it at all, and be careful not to heat steel any hotter than is necessary to produce this hardness. The better the article is polished the better the colors will show. Always leave tools as hard as they will stand. To make a tool extra tough draw the color a second time. After the color is drawn on a tool it should be cooled off enough to keep it from becoming softer. If articles are left in water very long after tempering the color will fade, and will disappear entirely if left in water a few hours. If you want color to remain on the article

dip it in oil just long enough to cool it. For tools that must be very hard, draw no color; heat them slowly to about 400 degrees to relieve strains, but not hot enough to draw any color, and allow it to cool in the air. If the color should start dip it into water or oil a few seconds. In this way you will leave the tool just as hard and a great deal tougher than it was when first hardened. Steel is a bad conductor of heat, and when a piece is dipped into a bath the surface cools and contracts first; the interior cools slower, and as it contracts the tendency is to pull away from the outside and enormous strains are developed; but when they are evenly distributed the steel is strong enough to resist them, but if there is more strain in one portion than another the steel is liable to crack. Tools with sharp corners in them will be far more liable to crack than they would if the corners were rounding, for square corners always invite strains. If you have many pieces to temper lay them on a hot piece of iron; for taps, reamers, drills, etc., heat a large nut or something of the sort, then pass the tool back and forth through the hole in the hot iron; turn it over often and watch the color closely. In drawing the temper on milling cutters and all articles having a large hole in the center, heat a round bar to a light red and put the article on the hot bar; this will draw the center the most and is the best way of drawing the temper when hot oil cannot be had.

Milling cutters, reamers, threading dies and drills should be tempered so that a good, fine, sharp file will take hold of them slightly. Taps should be tempered so a file will catch very little if any. Long arbors, mandrells, reamers, etc., that are liable to spring in hardening, should be made of a good grade of steel. Do not cut the bar cold. After cutting, heat the piece to a good red all over; stand it on end and give it two or three good blows on the end with a heavy hammer or sledge, depending upon the size of the piece; this will relieve strains caused by rolling or hammering; then thoroughly anneal it. The steel should be large enough so that all the decarbonized surface will be removed in machining. In all cases the steel should be at least one-eighth of an inch larger than the finished tool.

Arbors and mandrells should be hardened and reheated slightly, but not enough to start the slightest color.

HARDENING ANVILS.

To harden anvils or other large articles it is necessary to have a large bath, or one that has an overflow and inlet of fresh water so as to keep the bath from getting too hot. Another very important point is to get a nice, even heat and keep it moving in the bath until nearly cold, unless you can arrange so as to have a stream running on the face of the anvil. If a piece of red hot steel is plunged into a bath and held still, steam

will form around it and keep it from hardening properly. This is a very important point, especially when large pieces are to be hardened. Articles that are liable to spring in hardening should be moved up and down in the bath, but should not be moved sideways.

HARDENING AND TEMPERING HAMMERS.

Hammers and sledges should be heated evenly all over, but only harden the faces; leave heat enough in the middle to draw the temper in both ends. Hammers and sledges should be tempered so that a good file will take hold on the face. A hammer or sledge that you cannot file will be found to be too hard. It is far better to have a hammer too soft than too hard.

Before drawing the temper on any article have the surface polished nicely. If the surface is poorly polished the colors will not show nearly so well as on a surface that is well polished. If the polish is uneven the colors will not be uniform. The part that is poorly polished will show a darker color than the part that was well polished.

TEMPERING IN HOT OIL.

Drawing the temper in hot oil is the best way ever invented, and is generally used in connection with a gas furnace. Articles can be tempered to any degree to an absolute certainty in this way. Melted tallow is generally used for this purpose for it is capable of taking very high temperature, and can be kept at any temperature required for drawing temper by regulating the gas. The temperature of the oil can be determined by a thermometer partly immersed in the bath so that the bulb will be on a level with the work; in this way the exact heat required can be obtained, which eliminates the element of guess work from the process, providing the work has been hardened uniformly.

If you wish to draw an article to a straw color, adjust the heat of the bath to 460 degrees F. and dip the articles to be tempered in the hot tallow and keep them there long enough to become evenly heated clear through; that is all that is necessary. It will do no harm to leave the articles in the bath longer. The temper cannot get below a straw color as long as the bath remains at 460 degrees F. no matter if you should leave them in all day. For an article one-fourth of an inch thick six minutes will be long enough; three-eighths of an inch, eight minutes; one-half inch, ten minutes. The thicker the steel the longer it will take for the heat to penetrate it. If the steel is not uni-

formly hardened it cannot be evenly tempered by this method or any other. A man cannot work steel successfully unless he has his mind and eyes on his work.

I have often seen men put a piece of steel in the fire, turn on the blast and go to talking to some one and let the steel get to a white heat. Then they will say, "well, that is a little too hot, but it is not burned." A poor excuse, better than none. If a man cannot keep his mind on his work, he should work at something besides spoiling steel. Never complain about the steel not being good unless you know and can prove that it really is poor steel, or not the right kind of steel for that purpose. First be sure that you are right and know what you are talking about, then do not let any one bluff you.

Every man who has had much experience in hardening steel has seen what is generally called water cracks. These cracks are liable to occur when hardening articles that have thin edges and heavy bodies. Cold chisels sometimes crack in this way. These cracks never run straight and are always curved, and nearly always on only one side of the article. The cause of this sort of crack is the same as all others, viz., strains, and strains are either caused by uneven heating, uneven hammering or uneven contraction of the steel in cooling.

Some tool makers, machinists and foremen are in the habit of calling any and all kinds of cracks in steel

"water cracks." If a tool should break square in two three months after it had been hardened they would declare it to be a water crack, no matter how the fracture appeared, and regardless of how the tool had been used. It is useless to argue with such men for they imagine they know it all; but in reality they are like the Dutchman said: "Never knew nothing and always will."

There are a great many wrong theories advanced regarding steel and its proper treatment. A large per cent of the toolsmiths are old blacksmiths who are not able to do heavy work, so they are put on the tool fire. These old gentlemen think it is quite an honor to be promoted to toolsmith, and soon become imbued with the idea that they are expert steel workers. These old grandpas are always full of whims and all have their pet hobby regarding steel. One of them with whom I am acquainted claims steel should be hardened in ice water. Another tells us that long, round articles can be hardened without springing by stirring the bath in a circle as fast as possible and plunging the hot steel in the center of the whirl. He says "the water turning around it will keep it straight." Another says: "To keep steel from springing or cracking, put three or four handfulls of soot and one handfull of lime in the bath." What ridiculous nonsense. Strains are what causes steel to spring and crack. If a piece of steel has a strain in it, all the lime and soot in America cannot re-

move it, and stirring the bath in a circle will not help the matter in the least. Another expert tells us to dip all tools toward the north.

Never condemn anything unless you have thoroughly tested it and found it worthless.

Never advance a theory that you cannot prove.

Never argue about steel with a man who knows it all, for it is a useless waste of words.

Never conceive the idea that you know all about steel.

Never be in too great a hurry when heating steel.

Never overheat or unevenly heat steel.

Never use a very cold bath for hardening steel.

Never become careless when working steel.

Never forget to keep your mind and eyes on your work.

Never expose steel to heat any longer than necessary.

Never forget the instructions given in this little book, and you will become a successful steel worker.

THE HARDENING AND TEMPERING OF PUNCHES AND DIES.

Plate punches and dies are used extensively in boiler shops and structural works. They should be made of a good grade of steel, containing from 85 to 100 points of carbon. They should be heated in a suitable furnace standing in a vertical position, base down.

It is very important that an even heat be obtained, but no hotter than is actually necessary to produce thorough hardening. When the desired heat is obtained, remove them from the furnace and plunge them in the hardening bath, face downward.

Small punches and dies can be left in the bath until cold, but large ones should be moved around in the bath until they cease vibrating, then quickly removed and plunged into boiling water, which will eliminate all chance of cracking, and will leave the steel very hard, tough and strong.

After a few minutes they may be removed from the boiling water and allowed to cool in the air, or cooled in water. Then they should be nicely polished.

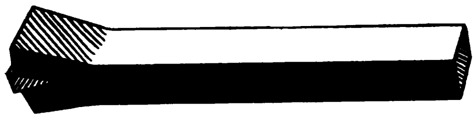
Now we are ready to draw the temper. To do this we should have a piece of iron or soft steel 1¼ inch thick, 10 or 12 inches wide by 14 inches long or larger. Drill several holes in one side, about ⅜ inch deep, and large enough to admit the points of the punches, so the punches will stand up, point downward. Heat the

block up to a good bright red and stand the punches on it, base down; let them stand in that position until a light straw color commences to show in necks, then turn them over with the points in the small holes; leave them there until the cutting edge turns blue, from 1-16 to 1-8 inch from the end; then plunge the punch into water. When cooled it is ready for use. Do not put too many punches on the hot iron at one time or you will not be able to catch the color.

If punches are too hard they will crush; if too soft they will buckle and smash down; if the base is too hard it will strip off in backing out; if the cutting end is too hard, it will also strip off in backing out, or else chip off. If the edge is too soft it will batter or wear quickly. Punches cannot be tempered all over alike. The neck and body must be left quite hard, so as to be very stiff; but the ends must be drawn to a blue, so as to be able to stand the work without stripping or chipping off. Dies should be tempered by placing them on a hot block face up. Let them remain until the face shows a dark straw color, then drop them in water and they are done.

When punches are to be heated in a forge great care must be used to obtain an even heat and to avoid over-heating.

1



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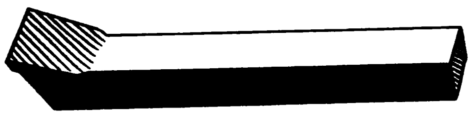

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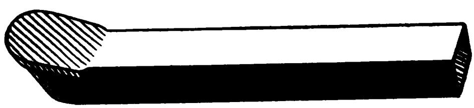

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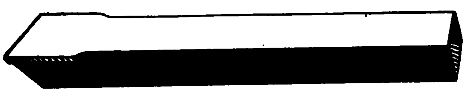

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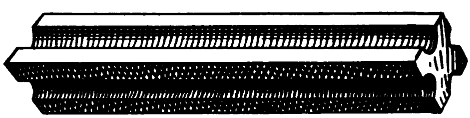


6

ROLL TURNING TOOLS.

There has been a great deal written about steel working, but all other writers forget to say anything about roll tools, or else they know nothing about this important branch of steel working. There are a great many shapes and sizes of roll tools and all kinds of steel has been tested on this line of work. Air hardened steel gives the best results for roughing tools, but a special grade of carbon steel gives the best results for finishing tools. These are generally turned or milled to shape, as shown in Cut No. 6, then heated to the proper refining heat and hardened in a good hardening solution and no temper drawn. Extra hardness may be obtained by using one of the hardening compounds in connection with the hardening solution. When hardening this class of tools be very careful to get an even heat and no hotter than is necessary to produce the desired hardness.

Roughing tools made of air hardened steel are very expensive, but this steel may be welded to soft steel and thus make an excellent tool with a soft steel body and air hardening steel face. This makes a better tool than the one made of air hardening steel throughout. They are not so easily broken and do not cost anywhere near as much.

To weld air hardening steel to soft steels it is absolutely necessary to have a good clean fire and a good

welding compound. Of those given in this book No. 9 is the best; of the prepared compounds which are on the market the E. Z. gives the best results. It is a safer method to first weld a piece of quarter inch Norway iron to the air hardening steel. Have the iron and steel the same length and width, so the iron will cover the one side of the steel. When you weld it draw one side to a blunt beveled edge. Then prepare the soft steel body. Forge the tool to shape, then with a hot cutter raise a lap scarf so the iron and steel face can be slipped under it from ¾ to 1¼ inches, depending on the size of the tool. Lay the iron and steel in place and hammer the scarf down over it closely, as shown in Cut No. 1. Of course the iron side of the face should be placed downward, so it will be between the tool steel and the soft steel. When this is done it is ready to weld. After welding the edges may be trimmed to shape.

This class of tools are generally wanted straight on the lower side and must have a lip on the upper or cutting side. When the tools are made of solid steel we upset the end so as to make the lip, but when they are made of soft steel and the face welded on we can easily get the same shape by splitting the soft steel in the middle and welding it in a V shaped wedge, as shown in Cut No. 2. This will throw the cutting edge up as much as desired and leave the bottom straight. After this is done, trim off the end and sides so as to give

the proper clearance, as shown in Cut Nos. 3 and 4. Smooth up the tool and allow it to cool off. Then it is ready to re-heat and harden. Never harden any tool of any kind of steel at the same heat it was forged at. If you wish to obtain the best results let the tool get cold, then re-heat and harden.

Directions for hardening the air hardening steels are always sent with the steel. Always follow the steel maker's instructions. There is a great difference in air hardening steels. Nearly all of them can be hardened successfully in oil. However, some will stand more heat than others. With this peculiar steel be sure you get it hot enough. It cannot be harmed by a bright yellow heat and some makes require a white heat. So long as you do not melt the edges off the heat is not too high. Most all smiths fail to get the best results from air hardening steel for the one reason, too low a heat. A good cold blast of air of sufficient force is the best means of hardening tools made of this steel. No doubt a great many smiths have an idea that air hardening steel can not be welded, but nevertheless it can be, and is being done every day in a very successful and satisfactory manner, thereby saving a great deal of money for the companies who are fortunate enough to have a steel worker in their employ who can weld this high priced steel. When making your first attempt at welding the steel be sure to get a good heat and do not get discouraged over a few failures.

CASE HARDENING.

It is generally understood that case hardening is the process of making the surface of a piece of soft steel or iron very hard. Webster gives the following definition: "To harden the outer part or superficies, as of iron, by converting it into steel, while the interior retains the toughness of malleable iron."

It is worth while to remember that the part to be case-hardened must be converted into carbon steel before it can be hardened. This can be done in various ways. Soft steel or iron will, under favorable circumstances and proper treatment, become carbonized (or converted into carbon steel) one-eighth of an inch deep in twenty-four hours' treatment. For articles that only require a slight surface hardening to prevent the corners from battering easily, as in cap screw heads, slot-headed screws, nuts, bolt heads, etc., the process is very simple. All that is necessary is to heat the article to a bright red and sprinkle it with pulverized Prussiate of Potash or Cyanide of Potash. Return it to the fire a few seconds, then harden it in cold water or brine. This will make the surface hard enough to resist the best file, but of course does not harden deep because the steel or iron was only exposed to the carbonizing element a few seconds.

A better way to case-harden with Cyanide of Potash is to place the articles in a large ladle and put in

enough Cyanide to cover them all; put the ladle in the fire and melt the Cyanide and heat to a red; keep it red hot for some time, for the longer the articles are kept red hot in the Cyanide the deeper they will harden. A large number of pieces can be hardened at one time in this way. When they have been in the red hot Cyanide long enough take them out and plunge them in the bath as mentioned before. Remember Cyanide of Potash is rank poison, so be careful. Do not put any wet article into melted Cyanide; if you do it will fly in all directions.

Another way to case harden is to pack the articles in an iron box with granulated raw bone and charred leather or charcoal; or bone and small pieces of leather may be used with good results. Place about one inch of bone and leather, or bone and charcoal, as the case may be, in the bottom of the box, then put in a layer of the pieces, but do not let them touch each other or come within one-half inch of each other, or within three-fourths of an inch of the sides of the box; fill in between the articles with the packing material and cover them about three-quarters of an inch deep; then put in another layer, and so on until the box is filled to within two inches of the top; then fill up with packing material and seal the lid tightly with fire clay. It is a good plan to have about four small holes drilled in the center of the box lid and run a small rod through each hole down between the articles to the

bottom of the box. The rods should be long enough to reach the bottom of the box and project above the lid about two inches. Put a little fire clay around each rod where it goes through the lid. The rods should be as large as will go through the hole easily. The holes should be about three-sixteenths of an inch in diameter. When this is done, place the box in the furnace and heat thoroughly to a good red and let it remain at that heat long enough to become heated evenly clear through; then pull out one of the rods; if it is red hot you will know that all the articles in the box are of the same heat. If only a thin surface hardening is wanted the work will be ready to harden as soon as it is brought to a good red; but if you want a deeper hardening it is necessary to keep them red hot for some time. If the first rod you remove does not show red hot, wait for a while and draw another and so on until the proper heat is reached. When ready to harden, remove the box from the furnace, take off the lid and dump the contents of the box into a sieve, shake out the packing material and plunge the articles into the bath as quickly as possible. Do not let them go into the bath all in a pile or they will not harden properly; scatter them around as much as possible. If the pieces are large they should not be dumped into the bath, but should be removed from the box one at a time and kept moving in the bath until nearly cold. If you wish the articles to be strong and hard take them

out of the box and let them cool in the air; then heat them again to a red and harden the same as tool steel, but draw no temper.

Articles treated in this way will show as fine a grain as tool steel; but if quenched when taken from the box they will be coarse grained and will not be nearly as strong as they would if allowed to cool in the air and then reheated and hardened.

You have all seen articles which were colored in case-hardening. To do this we must first have the articles nicely polished and perfectly clean. If you wish to produce colors, do not quench in any hardening solution; use clean, soft water. When the work is ready to harden, it is necessary to force air through the water so that it will bubble. The way I do this is to put a piece of small pipe in the bath and blow through it, then harden the article in the bubbling water. Work cannot be colored nicely if heated in a dirty fire, or exposed to the air or fire while heating. Nice colors can only be obtained by heating the articles in a muffle furnace, or in an air tight box or piece of pipe, or in melted Cyanide, as described before. Colors can also be had when the articles are packed in carbonaceous materials as described before, only use charred bone instead of raw bone. Articles will show the colors better if they are left in the water only just long enough to harden them, then removed while quite warm and cooled in oil. If thin or small pieces are to

be case-hardened, and you want them to be strong and not brittle, harden them in oil instead of water.

The Harveyizing method of case-hardening is as follows: Pack the articles in boxes as described before, only use charred leather or wood charcoal; do not use bone in this method; keep the work red hot for about eight hours, then remove the boxes from the furnace; when they are cold remove the work, reheat, and harden the same as tool steel. If you wish to harden extra deep, the articles should be packed in the boxes and heated twice. Before hardening this will carbonize the steel deeper and better than one packing. Soft steel case-hardened in this way will be as fine grained and as hard as tool steel. I have hardened milling cutters made of open hearth steel by this method which worked as good as cutters made of tool steel.

If you wish to case-harden part of an article and not the balance, copper plate the part you want soft: the carbon will not penetrate the copper, or the parts you want soft may be covered with fire clay to protect it from becoming carbonized. Another way to accomplish the same results is to machine to size only the parts you want hard, then pack in a box and carbonize. When cold, machine the part desired soft. This will remove the carbonized surface; then harden it; of course, the part that was machined after carbonizing will not harden.

For extra large pieces, or pieces that require an extra depth of hardening, it is best to use coarse bone and leather scrap and keep them red hot all day, or even two days. If one day's heat is not sufficient, let the work cool over night, then remove from the box and pack again in fresh material and return to the furnace.

When you harden large pieces of any kind keep them moving in the bath until nearly cold. If you do not keep large pieces moving while hardening the results will not be satisfactory, because the steam will keep the bath from coming in close contact with the steel and it will not cool quickly enough to harden properly. For case-hardening cultivator shovels and plow shares, use yellow Prussiate of Potash. To prevent plow shares from warping hammer evenly on both sides and dip straight in the bath. Do not overheat steel; give the work plenty of time to become carbonized. Follow these directions closely and you will be successful in case-hardening.

Another Way of Case Hardening.

For case hardening small articles splendid results can be obtained by the following process: Surround the article with yellow prusite of potash, then with leather, then with clay, pack in a piece of pipe, seal up both ends tightly with fire clay, heat to a good red and maintain the heat from four to six hours, then quench

in any good hardening solution or clear water, or the article may be allowed to cool off before removing from the packing box, then heat it and harden the same as tool steel.

Case Hardening Cast Iron.

To case harden cast iron heat to a good red and sprinkle thoroughly with the following compound:

Yellow Prusite of Potash	2 oz.
Salamoniac	2 oz.
Saltpeter	2 oz.

and plunge in a hardening bath.

BRAZING.

Brazing consists of uniting two pieces of metal with brass, copper, nickel or silver. Brass filings, soft sheet brass or spelter is generally used. To braze two pieces together we must first see that there is no dirt or grease on the articles, and that the surface, where the brazing is to be done, is bright and free from rust. We must also fix up some means of holding them together just as they are to be after they are finished. Now, when this is done, heat the joint red hot; put on a little powdered borax and then the brass filings, which will quickly melt and run into the joint and all around it; as soon as you see the brass has melted and run into the joint, remove it from the heat and cool in the air or water.

A band saw is an article that often breaks and can easily be brazed so it will be as strong as ever. I have brazed hundreds of them and never had one break where it had been brazed. To braze a band saw, first file or grind the ends to a thin point; of course, only grind or file on the flat sides; thin both ends down to a knife edge; taper them back about one inch; lap them together as far as you have tapered them; clamp the saw so as to hold it in line and right where you want it; have your clamp about one inch from the joint on each side; now take a thin piece of sheet brass the width of the saw and about one-fourth of an inch

longer than the splice is to be; put the piece of brass between the lapped ends of the saw; put a little powdered borax on top of the saw; have a pair of tongs with heavy bits about one inch square; heat them nearly to a welding heat, then grasp the saw at the splice with the hot tongs; hold it tightly until the brass melts, then remove the tongs carefully and allow the saw to cool; then file off the rough spots and smooth it up and your saw is ready to run again.

It is an easy matter to braze steel or wrought iron, but cast iron is very difficult to braze and cannot be done by the ordinary way of brazing. To braze cast iron we must first use a coating over the surface to be joined. The best coating is the Oxide of Copper made into the constituency of varnish and applied to the surface with a brush. Mix the Oxide of Copper with a strong solution of Borax and water to make the coating. The effect of this coating is to reduce the carbon on the surface of the cast iron to be brazed so that it passes somewhat into the nature of steel. Without this treatment the surface of cast iron, when heated, becomes slippery and will not braze. This reduction of carbon will penetrate for some distance into the cast iron. Heat in a muffle gas furnace or with a brazing torch; use brass filings, which will melt and run into the joint, at about 1,800 degrees F., and it will make a solid job fully as strong as solid cast iron.

Blow holes in castings can be filled in this way. First clean the hole and then coat it all over with the Oxide Varnish; heat it up to the brazing temperature and fill the hole full of melted cast iron; use a little spelter or brass filings; this will make the casting just as solid as it would have been if it had never had any blow hole. Brackets or any kind of projection can be brazed onto castings in this way.

MISCELLANEOUS.

A Chemical Mixture.

which will cut a hole in a file or other hardened steel or iron which cannot be drilled successfully:

Sulphate of Copper	1 oz.
Alum	¼ oz.
Pulverized Salt.	½ teaspoonful.
Nitric Acid	20 drops.
Vinegar	1 gill.

To cut a hole in steel with this mixture, first make a hole in a cake of beeswax the size you want the hole in the steel; then heat the beeswax a little and place it on the steel; then fill the hole with the mixture. If the above mixture is applied to steel, which has a polished surface, and washed off quickly, it will produce a beautiful, frosted appearance.

How to Re-Cut Files by a Chemical Process.

Dissolve four ounces of common soda in one quart of water; make enough of this solution to cover the files and boil them in it for half an hour; then take out, wash and dry them; stand them endways in a jar of sufficient depth and fill up the jar with rain water and put in four ounces of sulphuric acid to each quart of rain water. If the files are coarse they will need to remain in the solution about twelve hours; but for fine files eight hours will be sufficient. When you take them out wash them clean and dry them quickly and put on a little sweet oil to keep them from rusting. Files may be re-cut in this way two or three times. The solution may be kept and used as long as you see action take place when you put the files into it. Keep it tightly covered when not in use.

The object of boiling the files in the soda solution is to remove all grease and dirt. The action of the acid thins the teeth and leaves a sharp edge. By using this method you can get double the amount of service. The cost of re-cutting is very small.

Writing on Metals.

For writing on iron, steel, brass, copper, etc., use the following mixture:

Muriatic Acid------------------1 oz.
Nitric Acid--------------------½ oz.

Mix together. Cover the article you wish to write on with beeswax; when cold write plainly what you want in the beeswax with a sharp pointed piece of steel; be sure to get clear down to the metal and clean all the wax out of the letters. Then apply the solution with a feather; fill all the letters carefully; let it remain from two to ten minutes, according to the depth of the letters desired; then put on some water which will dilute the acid and stop the action; now clean off the beeswax and put on a little oil. Either of the acids alone will cut iron or steel, but it requires them both to cut brass, copper, nickel or silver. Hard soap may be used instead of beeswax, but the wax is the best. If you wish to write on some article that is rounding, so that the acid will not stay in the letters, you can cover the article on all sides with wax; then dip it in the solution in such a way that the acid will cover the letters. This mixture will cut a hole in steel or iron which is too hard to drill. Paraffine may be used in place of beeswax with fully as good results as soap.

HOW TO BUILD A FURNACE.

A furnace for heating steel, for hardening and annealing should be in every shop, for it is impossible to get a satisfactory heat in a forge for hardening tools. A forge is all right for cold chisels, lathe and planer tools, etc., but for taps, dies, reamers, shear knives, milling cutters, etc., a furnace should always be used. A furnace can be easily and cheaply built and will pay for itself in a short time.

The furnace should be built of fire brick and of proper size to suit the class of work which it is to be used for, and should be arched over the top and have an iron door about twenty-four inches wide by twelve or fourteen inches high. The door should be lined with fire brick, and should have a one and one-half inch hole in the center so that the operator can see the work. The door should be nicely balanced by means of a lever and weight which should be above the door and of sufficient height to be out of the way. There should be a small rod attached to the lever so that the operator can open the door by pulling the rod. If the door is properly balanced it will remain in any position, and will be easily opened or closed. The fire bed is an important feature in this kind of a furnace. Any ordinary grate bars with one-half inch openings will do. The bars should be firmly set so as to make a solid, level bed. The fire bed should be about two

feet from the floor; the fore plate should be five or six inches above the grate bars. Another important feature is the stack, which should be of sufficient size and height to give the furnace a good draft, and should have a good damper so it can be closed perfectly tight.

Hard coke is the only satisfactory fuel for this kind of a furnace. Kindle the fire with wood, then fill the furnace up level with the fore plate with small pieces of coke. Leave the damper open until the furnace gets to the proper heat then close it and put in the work.

This kind of a furnace does not require any blast. If you wish to use it for heating or forging purposes leave the damper open. A welding heat can be obtained if desired, but for hardening and annealing purposes be careful not to get the furnace too hot, and keep the damper closed, or nearly so, while the steel is heating.

For heating small articles, lay them on a piece of iron about one-fourth of an inch thick and of sufficient size to hold the pieces; then place them in the furnace on the plate. Turn the steel over while heating so as to get a perfectly even heat.

The entire expense of making such a furnace would not exceed $50. I have used furnaces of this description on all classes of work with good results.

TO SOLDER IRON OR OTHER METALS WITHOUT FIRE.

Take 1 oz. sal-ammoniac and 1 oz. of common salt, and an equal amount of calcined tartar and as much of bell metal filings, and 3 oz. of antimony. Pound well all together and sift it. Put this into a piece of linen and enclose it well all round with Fuller's earth about an inch thick. Let it dry, then put it between two crucibles over a slow fire, heat slowly until the lump becomes red hot and melted all together; then allow it to cool slowly, when cold pound it into powder. When you wish to solder anything put the two pieces on a bench or table, place the ends together; make a cast of Fuller's earth around the joint; but open on top. Place some of the powder between and around the joint. Have some borax and put it into hot spirits of wine until it is consumed, then with a feather wet the powder at the joint, it will boil immediately, as soon as boiling stops the consolidation is made, if any rough spots exist grind them off. Fork prongs or casting can be put together in this way and make a good strong joint.

Weight and Specific Gravity of Metals.

METALS	Weight per Cubic Ft. Pounds	Weight per Cubic In. Pounds	Specific Gravity
Aluminum	166	.096	2.67
Antimony, cast	419	.242	6.72
Bismuth	613	.3	8.4
Bronze	534	.308	8.561
Copper, cast	537	.31	8.607
Copper, wire	555	.32	8.08
Gold, 24 carat	1208	.697	19.361
Gold, standard	1106	.638	17.724
Gun metal	528	.304	8.459
Iron, cast	450	.26	7.21
Iron, wrought	485	.28	7.78
Lead, cast	708	.408	11.36
Lead, rolled	711	.41	11.41
Mercury	849	.489	13.596
Platinum	1344	.775	21.531
Platinum, sheet	1436	.828	23.
Silver, pure	654	.377	10.474
Silver, standard	644	.371	10.312
Steel	490	.284	7.85
Tin, cast	455	.262	7.291
Zink	437	.252	7.

CAPACITY OF CYLINDRICAL CISTERNS.

This Table Gives Capacity in Gallons for Each Foot in Depth.

DIAMETER	GALLONS	DIAMETER	GALLONS
2 feet	19	8 ft.	319
2½ feet	30	9 ft.	396
3 feet	44	10 ft.	489
4 feet	78	11 ft.	592
4½ feet	99	12 ft.	705
5 feet	122	13 ft.	827
6 feet	176	14 ft.	959
6½ feet	206	15 ft.	1101
7 feet	239	20 ft.	1958

WEIGHTS AND MEASURES.

Troy Weight.

24 grains—one pennyweight (pwt).
20 pennyweights—one ounce (oz.) 480 grains.
12 ounces—one pound (lb.) 5760 grains.
20 grains—one scruple.
3 scruples—one dram, 60 grains.
8 drams—one ounce, 480 grains.

Avoirdupois Weight.

27⅛ grains—one dram.
16 drams—one ounce, 437½ grains.
16 ounces—one pound, 7000 grains.
2000 pounds—one ton.

Liquid Measure.

4 gills—one pint (pt.), 28.⅞ cubic inches.
2 pints—one quart (qt.), 57.¾ cubic inches.
4 quarts—one gallon (gal.), 231. cubic inches.
32 gallons—one barrel (bbl.)
63 gallons—one hogshead (hhd.)

Dry Measure.

2 pints—one quart, 67.¼ cubic inches.
4 quarts—one gallon, 268.8025 cubic inches.
2 gallons—one peck, 537.605 cubic inches.
4 pecks—one bushel, 2150.42 cubic inches.

Long Measure.

12 inches—one foot (ft.)
3 feet—one yard (yd.), 36 inches.
5½ yards—one rod (rd.), 16½ feet.
40 rods—one furlong (fur.), 660 feet.
8 furlongs—one mile (m.), 5280 feet.
3 miles—one league, 15840 feet.

Square Measure.

144 square inches—one square foot.
9 square feet—one square yard.
30¼ square yards—one square rod.
40 square rods—one square rood.
4 square roods—one square acre.
640 square acres—one square mile.

Useful Numbers in Calculation.

Diam. of circle	×	3.1416	=circumference.
Circumference	×	.3183	=diameter.
Square of diam.	×	.7854	=area.
Radius	×	6.2831	=circumference.
Diameter	×	.88622	=side of equal square.
Side of square	×	1.128	=Diam. of circle of equal area
Cubic inches	×	.003607	=gallons.
Cubic feet	×	6.232	=gallons.
Cylindrical in.	×	.002832	=gallons.
Cubic inches	÷	277.274	=gallons.
Cylindrical in.	÷	353.03	=gallons.
Cubic ft. water	×	35.9	=tons.
Gals. of water	×	10.	=pounds.

Melting Points of Metals.

METALS	CENTIGRADE	FAHRENHEIT
Aluminum	700	1,292
Antimony	425	797
Arsenic	185	365
Bismuth	264	507.2
Cadmium	320	608
Cobalt	1,200	2,192
Copper	1,091	1,995.8
Gold	1,381	2,485.8
Indium	176	348.8
Iron, wrought	1,530	2,786
Iron, cast	1,200	2,192
Lead	334	617
Magnesium	235	455
Nickel	1,600	2,912
Potassium	62	143.6
Platinum	2,600	4,712
Steel	1,400	2,552
Silver	1,040	1,904
Sodium	96	172.8
Tin	235	455
Zink	412	773.6

To Blue Steel Without Heating.

To blue steel without heating, cover the surface with nitric acid, then wipe the acid off clean, oil the article and burnish.

By using turpentine instead of oil hard material, such as spring steel, saw plate, hard steel, etc., can be drilled or machined when it would have been impossible with oil. Adding as much camphor gum to the turpentine as it will dissolve will greatly improve it, and by the use of it glass can be drilled and taped. To drill glass use an extra hard flat drill with but very little clearance.

Lubricant for Machining Aluminum.

Kerosene oil is the best known lubricant for working aluminum.

Lubricant for Improving Water Cuts.

Strong soap water or sal soda water is far better than clear water for taking water cuts on any machine.

To Harden Tools for Cutting Extra Hard Material.

Heat carefully to the refining heat and plunge into quick silver or a lump of resin. Another method of making a tool extra hard is to apply the following compound:

Carbonate of soda..............1 oz.
Carbonate of potash............1 oz.
Cyanide of potash..............1 oz.

to be pulverized thoroughly and mixed together. Heat the tool red hot and dip in the compound for a few seconds, then return it to the fire until the proper heat is obtained, then plunge the tool in quick silver or any good hardening bath. This will make a tool hard enough to cut glass, chilled cast iron or anything else that steel is supposed to cut. Draw no temper after using these methods.

To Harden Cast Iron.

Heat to a good red and sprinkle with the following compound. Keep the article at a good red for a few seconds and plunge in any good hardening solution.

Salt ....2 lbs.
Saltpeter ....½ lb.
Alum ....½ lb
Salts of Tartar..............¼ oz.
Cyanide of Potash............1 oz.
Carbonate of Ammonia.........6 oz.

draw no temper after using this compound.

To Harden Very Small Drills.

Heat carefully and plunge into a lump of tallow and beeswax, equal parts. Draw no temper.

To Harden Thin Knife Blades.

Heat to a cherry red and plunge edge downward in a cake of common yellow soap. Draw no temper.

To Drill Chilled Cast Iron.

First heat the casting red hot where it is to be drilled and place a small ferrell full of brimstone where the hole is to be drilled. When the casting gets cold it will be found that the spot exposed to the brimstone will be very soft.

To Detect Iron From Steel.

It is difficult to distinguish between iron and steel when both are polished. To make the distinction easily and quickly use diluted nitric acid, four parts water to one of acid, place a drop of the solution on the polished surface. If it remains bright it is iron, if a black spot is formed, it is steel. The spot can be easily rubbed off.

To Make a Hole in Glass.

Stick a piece of stiff clay or putty on the glass. Make a hole in it of the size desired. Into the hole pour a little molten lead. The glass exposed to the lead will immediately drop out unless it is very thick.

Things That Will Never be Settled.

The proper length of a family screw driver.

The proper length of a blacksmith's hammer handle.

The best bath for hardening steel.

Why steel hardens.

The proper speed for line shafts.

The right way to lace belts.

How to make the best welding compound.

How to harden copper.

Common Names of Chemical Substances.

Aqua Fortis	*Nitric acid.*
Aqua Regia	*Nitro-Muriatic acid.*
Blue vitriol	*Sulphate of copper.*
Cream of tartar	*Bitartrate of Potassium.*
Calomel	*Cloride of Mercury.*
Chalk	*Carbonate of calcium.*
Salt of tartar	*Carbonate of Potassa.*
Caustic Potash	*Hydrate of Potassium.*
Chloroform	*Chloride of Gromyle.*
Common salt	*Chloride of Sodium.*
Copperas(green vitroil)	*Sulphate of Iron.*
Corrosive sublimate	*Bichloride of Mercury.*
Diamond	*Pure carbon.*
Dry alum	*Sulphate aluminum and Potassium.*

Epsom salts	*Sulphate of magnesia.*
Ephiops Mineral	*Black sulphate of mercury.*
Fire damp	*Light carburetted hydrogen*
Galena	*Sulphide of lead.*
Glucose	*Grape sugar.*
Iron pyrites	*Bisulphide of iron.*
Jeweler's putty	*Oxide of tan.*
King's yellow	*Sulphide of arsenic.*
Laughing gas	*Protoxide of nitrogen.*
Lime	*Oxide of calcium.*
Lunar caustic	*Nitrate of silver.*
Mosaic gold	*Bisulphide of tin.*
Muriate of lime	*Chloride of Calcium.*
Niter or saltpeter	*Nitrate of potash.*
Oil of vitriol	*Sulphuric acid.*
Potash	*Oxide of potassium.*
Red lead	*Oxide of lead.*
Rust of iron	*Oxide of iron.*
Salammoniac	*Muriate of ammonia.*
Slacked lime	*Hydrate of calcium.*
Soda	*Oxide of Sodium.*
Spirits of Hartshorn	*Ammonia.*
Spirits of salt	*Hydrochloric acid.*
Stucco (plaster paris)	*Sulphide of lead.*
Sugar of lead	*Acetate of lead.*
Verdigris	*Basic acetate of copper.*
Vermilion	*Sulphide of mercury.*
Vinegar	*Acetic acid (dilute).*

Volatile alkali............*Ammonia.*
Water ....*Oxide of hydrogen.*
White precipitate.........*Ammoniate mercury.*
White vitriol............. *Sulphate of zink.*

THE SECRET OF CAST STEEL.

The history of cast steel presents a curious instance of a manufacturing secret stealthily obtained under the cloak of an appeal to philanthropy. The main distinction between iron and steel, as most people know, is the latter contains carbon. Iron is converted into steel by being heated for a considerable time in contact with powdered charcoal inclosed in an oven or crucible so as to exclude the air. Now, steel thus made is unequal. The middle of the bar is more carbonized that the ends, and the surface more than the center. It is therefore, unreliable. Nevertheless before the invention of cast steel there was nothing better.

In 1760 there lived at Attercliffe, England, a watch maker named Huntsman. He became dissatisfied with the watch springs in use and set himself to the task of making them homogeneous. If, thought he, I can melt a piece of steel and cast it into an ingot its composition will be the same throughout. He succeeded. His steel soon became famous. Huntsman's ingots for fine work were in universal demand. He did not call them cast steel. That was his secret.

About 1780 a large manufactory of this peculiar steel was established at Attercliffe. The process was wrapped in secrecy by every possible means. One midwinter night a traveler knocked at the gate. It was bitterly cold and the snow fell fast and the wind howled across the moat. The stranger, apparently a farm laborer seeking shelter from the storm, awakened no suspicion. Scanning the wayfarer closely, and moved by motives of humanity, the foreman granted his request and let him in. Feigning to be worn out by the cold and fatigue, the fellow sank upon the floor and soon appeared to be asleep. That, however, was far from his intention. He closed his eyes apparently only. He saw workmen cut bars of steel and iron into bits, place them in crucibles and thrust them into a furnace. The fire was urged to its extreme power until the steel melted. Clothed in wet rags to protect themselves from the heat, the workmen drew out the glowing crucibles and poured their contents into molds. Mr. Huntsman's factory had nothing more to disclose. The secret of making cast steel had been discovered.

MECHANICAL RULES.

To Find the Circumference of a Circle When the Diameter is Given.

Rule No. 1. Multiply the diameter by 3 1-7, or multiply the diameter by 22 and divide the product by 7, or multiply the diameter by 3.1416, or for greater accuracy use 3.141592653.

To Find the Circumference of a Circle When the Area is Given.

Rule No. 2. Multiply the area by 12.566 and extract the square roof of the product.

To Find the Diameter of a Circle When the Circumference is Given.

Rule No. 3. Divide the circumference by 3.1416 or multiply the circumference by .31831. Example: The circumference of a given circle is 22 feet, find the diameter.

Operation: $.31831 \times 22 = 7.00282$ ft. diameter.

To Find the Diameter of a Circle When the Area is Given.

Rule No. 4. Multiply the area by 1.2732 and extract the square root of the product.

To Find the Area of a Circle When the Diameter is Given.

Rule No. 5. Square the diameter and multiply the product by .7854 or square the radius and multiply by 3.1416.

To Find the Area of a Circle When the Circumference is Given.

Rule No. 6. Multiply half of the circumference by the radius or square the circumference and multiply by .07957747.

To Find the Area of an Equilateral Triangle.

Rule No. 7. Multiply the square of one side by .433013. (Note, an equilateral triangle is a figure with three equal sides). Example: What is the area of an equilateral triangle which measures five inches on each side?

Operation: $5\times5=25$ (square of one side) $\times$ $.433013=10.815325$ square inches, area.

To Find the Area of a Square or Rectangle.

Rule No. 8. Multiply the length by the breadth. Example: What is the area of end of a bar 2x4 steel? Operation: $2\times4=8$ square inches, area.

To Find the Area of a Hexagon.

Rule No. 9. Multiply the square of one side by 2.598. Example: What is the area of the end of a

hexagon bar which measures 9-16 inch on each side? Operation: 9-16×9-16=.5625×.5625=335+ (square of one side); .335×2.598=.870+ square inches, area.

To Find the Area of an Octagon.

Rule No. 10. Multiply the square of one side by 4.8284. Example: What is the area of the end of an octagon bar which measures 3/8 inch on each side. Operation: 3/8=.375; .375×.375=.1388 (square of one side); .1388×4.8284=.68578 square inches, area.

To Find the Cubic Contents of a Bar in Inches.

Rule No. 11. Multiply the area of one end in inches by the length of bar in inches. Example: What is the cubic contents of a bar of 1/2x1/2 12 feet long, (144 inches)? Operation: 1/2×1/2=1/4 inches, area (of one end); 1/4×144=36 cubic inches.

To Find the Weight of a Bar of Steel.

Rule No. 12. Multiply the cubic contents in inches by .283.

Wrought Iron.—Multiply the cubic contents in inches by .278.

Cast Iron.—Multiply the cubic contents in inches by .26.

The product will be the weight in pounds. A wrought iron bar one inch square and one foot long weighs 3 1-3 pounds, or 10 pounds to the yard. Steel is about two per cent heavier than iron. With the fore-

going rules and tables it will be found an easy matter to figure the weights of bars of all sizes and shapes. For example: What is the weight of a six inch round bar of iron ten feet long (120 inches), refer to rule No. 5. To find the area of a circle we square the radius. The radius of a six inch circle is three inches 3×3=9, square of radius; 9×3.1416=28.2744 square inches area; 28.2744×120 inches long=3392.928 cubic inches ×.278=943.23 pounds, weight of bar.

To Find the Cubic Contents and Weight of a Ball.

Rule No. 13. Multiply the cube of the diameter by .5236. Example: What is the cubic contents and weight of a cast iron ball 6 inches in diameter? Operation: 6×6×6=216, cube of diaemeter; 216×.5236=113.0976 cubic inches. 113.0976×.26, weight of one cubic inch of cast iron=29.4.

To Find the Diameter of a Ball When Weight is Given.

Rule No. 14. Divide the weight of the ball by the weight of the metal per cubic inch and divide the product by .5236 and extract the cube root. Example: What is the diameter of a ball of cast iron which weighs 17.017 lbs.? Operation: 17.017 divided by .26=65.45 cubic inches. 65.45 divided by .5236=125. The cube root of 125=5 inches, diameter of ball.

To Find the Diameter of a Hexagon Across Corners When the Diameter Across Flats is Given.

Rule No. 15. Multiply the diameter across flats by 1.156. Example: What is the diameter across corners of a three-quarter inch hexagon. Operation: $\frac{3}{4}=.75$: $1.156 \times .75 = .867$ inch.

To Find the Cubic Contents of a Square Ended Cylinder.

Rule No. 16. Find the area of one end by rule No. 5, multiply the area by the length. The product will be the cubic contents. Note: Dimensions are to be taken all in inches or all in feet.

To Find the Area of a Triangle.

Rule No. 17. Multiply the length of the base, by perpendicular height, and divide the product by 2. The quotient will be the area. When the triangle is equilateral or equal sided the area can be calculated by squaring one side, dividing the square by four and multiply the quotient by 1.732 or by rule No. 7.

To Find the Circumference of an Ellipse.

Rule No. 18. Add the two diameters together, divide the sum by 2, multiply the quotient by 3.1416.

To Find the Area of an Ellipse.

Rule No. 19. Multiply the two diameters together and multiply the product by .7854. The final product will be the area.

To Find the Area of a Sector of a Circle.

Rule No. 20. Multiply half the length of the arc by the radium of the circle. The product will be the area of the sector.

Mechanical Rules and Tables

Diameter and Circumference of Circles.

EXPLANATION OF THE FOLLOWING TABLES.

To find the circumference of a circle when the diameter is given, we multiply the diameter by 3.1416. A shorter method is to multiply the diameter by 3 1-7; or multiply the diameter by 22 and divide by 7. The following tables commence at one inch and advance by one-eighth of an inch up to twenty feet. In making rings or bands of any size of iron or steel, we must add the thickness of the iron to the diameter and get the circumference on that size.

Example: If you wish to make a ring 40 inches in diameter out of 2¼ inch square iron, to the diameter, 40 inches, add the thickness of the iron, 2¼ inches, which equals 42¼ inches, or 3 ft. 6¼ inches. Refer to the tables for the circumference of a 3 ft. 6¼ inch circle; you will find it to be 11 ft. and ¾ inches. Cut off your iron 11 ft. ¾ inches long plus enough for making the weld, scarf the ends, bend and weld it and you will have a ring 40 inches in diameter inside measure.

The thicker the iron the more it will take up in bending. It will take 19 ft. 1⅜ inches of iron, one inch thick, to make a ring 6 ft. in diameter; and will take 19 ft. 10¾ inches of iron four inches thick, to make a ring. 6 ft. in diameter. A circle 7 ft. in diameter will be 22 ft. in circumference.

When making rings always add the thickness of the iron to the inside diameter and refer to the tables for circumference. The tables will be found correct and useful to any man who has rings or bands to make.

These tables give the length of iron or steel required to form a ring but do not make allowance for the weld. Always allow enough for the weld over the length given in the tables. Iron requires a little more for a weld than steel, and some men take up more stock in making a weld than others do, so no exact amount can be specified. Usually one-half the thickness of the stock will be sufficient for steel.

Mechanical Tables

TABLE NO. 1.—1 in. to 1 ft. 4⅞ in.

DIAM. IN.	CIR. FT. IN.	DIAM. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
1	0. 3⅛	5	1. 3⅝	0. 9	2. 4¼	1.1	3 4⅞
1⅛	0. 3½	5⅛	1. 4	0. 9⅛	2. 4⅝	1.1⅛	3. 5¼
1¼	0. 3⅞	5¼	1. 4½	0. 9¼	2. 5	1.1¼	3. 5⅝
1⅜	0. 4¼	5⅜	1. 4⅞	0. 9⅜	2. 5½	1.1⅜	3. 6
1½	0. 4⅝	5½	1. 5¼	0. 9½	2. 5⅞	1.1½	3. 6⅜
1⅝	0. 5	5⅝	1. 5⅝	0. 9⅝	2. 6¼	1.1⅝	3. 6¾
1¾	0. 5½	5¾	1. 6	0. 9¾	2. 6⅝	1.1¾	3. 7⅛
1⅞	0. 5⅞	5⅞	1. 6½	0. 9⅞	2. 7	1.1⅞	3. 7⅝
2	0. 6¼	6	1. 6⅞	0.10	2. 7⅜	1.2	3. 8
2⅛	0. 6⅝	6⅛	1. 7⅛	0 10⅛	2. 7¾	1.2⅛	3. 8⅜
2¼	0. 7	6¼	1 7⅝	0.10¼	2. 8¼	1.2¼	3. 8¾
2⅜	0. 7½	6⅜	1. 8	0.10⅜	2. 8½	1.2⅜	3. 9⅛
2½	0. 7⅞	6½	1. 8⅜	0.10½	2. 9	1.2½	3. 9½
2⅝	0. 8¼	6⅝	1. 8¾	0.10⅝	2. 9⅜	1.2⅝	3. 9⅞
2¾	0. 8⅝	6¾	1. 9¼	0.10¾	2. 9¾	1.2¾	3.10⅜
2⅞	0. 9	6⅞	1. 9½	0.10⅞	2.10⅛	1.2⅞	3.10¾
3	0. 9⅜	7	1.10	0.11	2.10½	1.3	3.11⅛
3⅛	0. 9¾	7⅛	1.10⅜	0.11⅛	2.10⅞	1.3⅛	3.11½
3¼	0.10¼	7¼	1.10¾	0.11¼	2.11⅜	1.3¼	3.11⅞
3⅜	0.10½	7⅜	1.11⅛	0.11⅜	2.11¾	1.3⅜	4. 0¼
3½	0.11	7½	1.11½	0.11½	3. 0⅛	1.3½	4. 0⅝
3⅝	0.11⅜	7⅝	1.11⅞	0.11⅝	3. 0½	1.3⅝	4. 1
3¾	0.11¾	7¾	2. 0⅜	0.11¾	3. 0⅞	1.3¾	4 1⅜
3⅞	1. 0⅛	7⅞	2. 0¾	0.11⅞	3. 1¼	1.3⅞	4. 1⅞
4	1. 0½	8	2. 1⅛	1. 0	3. 1⅝	1.4	4. 2¼
4⅛	1. 0⅞	8⅛	2. 1½	1. 0⅛	3. 2	1.4⅛	4. 2⅝
4¼	1. 1⅜	8¼	2. 1⅞	1. 0¼	3. 2½	1.4¼	4. 3
4⅜	1. 1¾	8⅜	2. 2⅜	1. 0⅜	3. 2⅞	1.4⅜	4. 3⅜
4½	1. 2⅛	8½	2. 2¾	1. 0½	3. 3¼	1.4½	4. 3¾
4⅝	1. 2½	8⅝	2. 3	1. 0⅝	3. 3⅝	1.4⅝	4. 4⅛
4¾	1. 2⅞	8¾	2. 3½	1. 0¾	3. 4	1.4¾	4. 4½
4⅞	1. 3¼	8⅞	2. 3⅞	1. 0⅞	3. 4⅜	1.4⅞	4. 5

TABLE NO. 2.—1 ft. 5 in. to 2 ft. 8⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
1.5	4. 5⅜	1. 9	5. 5¾	2 1	6. 6½	2.5	7. 7
1 5⅛	4. 5¾	1. 9⅛	5. 6⅜	2.1⅛	6. 6⅞	2.5⅛	7. 7½
1.5¼	4. 6⅛	1. 9¼	5. 6¾	2.1¼	6. 7¼	2.5¼	7. 7⅞
1.5⅜	4. 6½	1. 9⅜	5. 7⅛	2.1⅜	6. 7⅝	2.5⅜	7. 8¼
1.5½	4. 7	1. 9½	5. 7½	2.1½	6. 8¼	2.5½	7. 8⅝
1 5⅝	4. 7⅜	1. 9⅝	5. 8	2.1⅝	6. 8½	2.5⅝	7: 9
1.5¾	4. 7¾	1. 9¾	5. 8⅜	2.1¾	6. 8⅞	2.5¾	7. 9⅜
1.5⅞	4. 8⅛	1. 9⅞	5. 8¾	2.1⅞	6. 9¼	2.5⅞	7. 9¾
1.6	4. 8½	1.10	5. 9⅛	2.2	6. 9⅝	2.6	7 10¼
1.6⅛	4. 8⅞	1.10⅛	5. 9½	2.2⅛	6.10	2.6⅛	7.10⅝
1.6¼	4. 9¼	1.10¼	5. 9⅞	2.2¼	6.10½	2.6¼	7.11
1.6⅜	4. 9⅝	1.10⅜	5.10¼	2.2⅜	6.10⅞	2.6⅜	7.11⅜
1.6½	4.10⅛	1.10½	5.10⅝	2.2½	6.11¼	2.6½	7.11¾
1.6⅝	4.10½	1.10⅝	5.11	2.2⅝	6.11⅝	2.6⅝	8. 0⅛
1.6¾	4.10⅞	1.10¾	5.11½	2.2¾	7. 0	2.6¾	8. 0½
1.6⅞	4.11¼	1.10⅞	5.11⅞	2.2⅞	7. 0⅜	2.6⅞	8. 1
1.7	4.11⅝	1.11	6. 0¼	2.3	7. 0¾	2.7	8 1⅜
1.7⅛	5. 0	1.11⅛	6. 0⅝	2.3⅛	7. 1⅛	2.7⅛	8. 1¾
1.7¼	5. 0⅜	1.11¼	6. 1	2.3¼	7. 1½	2.7¼	8. 2⅛
1.7⅜	5. 0⅞	1.11⅜	6. 1⅜	2.3⅜	7. 2	2.7⅜	8. 2½
1.7½	5. 1¼	1.11½	6. 1¾	2.3½	7. 2⅜	2.7½	8. 2⅞
1.7⅝	5. 1⅝	1.11⅝	6. 2¼	2.3⅝	7. 2¾	2.7⅝	8. 3⅜
1.7¾	5. 2	1.11¾	6. 2⅝	2.3¾	7. 2⅛	2.7¾	8. 3¾
1 7⅞	5. 2⅜	1.11⅞	6. 3	2.3⅞	7. 3½	2.7⅞	8. 4⅛
1.8	5. 2¾	2. 0	6. 3⅜	2.4	7. 3⅞	2.8	8. 4½
1.8⅛	5. 3⅛	2. 0⅛	6. 3¾	2.4⅛	7. 4⅜	2.8⅛	8. 4⅞
1.8¼	5. 3⅝	2. 0¼	6. 4⅛	2.4¼	7. 4¾	2.8¼	8. 5¼
1.8⅜	5. 4	2. 0⅜	6. 4½	2.4⅜	7. 5⅛	2.8⅜	8. 5⅝
1.8½	5. 4⅜	2. 0½	6. 4⅞	2.4½	7. 5½	2.8½	8. 6
1.8⅝	5. 4¾	2. 0⅝	6. 5⅜	2.4⅝	7. 5⅞	2.8⅝	8. 6½
1.8¾	5. 5⅛	2. 0¾	6. 5¾	2.4¾	7. 6¼	2.8¾	8. 6⅞
1.8⅞	5 5½	2. 0⅞	6. 6⅛	2.4⅞	7. 6⅝	2.8⅞	8. 7¼

TABLE NO. 3.—2 ft. 9 in. to 4 ft. 0⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
2. 9	8. 7⅝	3. 1	9. 8¼	3. 5	10. 8¾	3. 9	11. 9⅜
2. 9⅛	8. 8	3. 1⅛	9. 8⅝	3. 5⅛	10. 9⅛	3. 9⅛	11. 9¾
2. 9¼	8. 8⅜	3. 1¼	9. 9	3. 5¼	10. 9½	3. 9¼	11. 10⅛
2. 9⅜	8. 8⅞	3. 1⅜	9. 9⅜	3. 5⅜	10. 9⅞	3. 9⅜	11. 10½
2. 9½	8. 9¼	3. 1½	9. 9¾	3. 5½	10. 10⅜	3. 9½	11. 10⅞
2. 9⅝	8. 9⅝	3. 1⅝	9. 10⅛	3. 5⅝	10. 10¾	3. 9⅝	11. 11¼
2. 9¾	8. 10	3. 1¾	9. 10½	3. 5¾	10. 11⅛	3. 9¾	11. 11⅝
2. 9⅞	8. 10⅜	3. 1⅞	9. 10⅞	3. 5⅞	10. 11½	2. 9⅞	12. 0⅛
2. 10	8. 10¾	3. 2	9. 11⅜	3. 6	10. 11⅞	3. 10	12. 0½
2. 10⅛	8. 11⅛	3. 2⅛	9. 11¾	3. 6⅛	11. 0⅜	3. 10⅛	12. 0⅞
2. 10¼	8. 11½	3. 2¼	10. 0⅛	3. 6¼	11. 0¾	3. 10¼	12. 1¼
2. 10⅜	9. 0	3. 2⅜	10. 0½	3. 6⅜	11. 1⅛	3. 10⅜	12. 1⅝
2. 10½	9. 0⅜	3. 2½	10. 0⅞	3. 6½	11. 1½	3. 10½	12. 2
2. 10⅝	9. 0¾	3. 2⅝	10. 1⅜	3. 6⅝	11. 1⅞	3. 10⅝	12. 2⅜
2. 10¾	9. 1⅛	3. 2¾	10. 1¾	3. 6¾	11. 2¼	3. 10¾	12. 2⅞
2. 10⅞	9. 1½	3. 2⅞	10. 2⅛	3. 6⅞	11. 2⅝	3. 10⅞	12. 3¼
2. 11	9. 1⅞	3. 3	10. 2½	3. 7	11. 3	3. 11	12. 3⅝
2. 11⅛	9. 2⅜	3. 3⅛	10. 2⅞	3. 7⅛	11. 3½	3. 11⅛	12. 4
2. 11¼	9. 2¾	3. 3¼	10. 3¼	3. 7¼	11. 3⅞	3. 11¼	12. 4⅜
2. 11⅜	9. 3⅛	3. 3⅜	10. 3⅝	3. 7⅜	11. 4¼	3. 11⅜	12. 4¾
2. 11½	9. 3½	3. 3½	10. 4	3. 7½	11. 4⅝	3. 11½	12. 5¼
2. 11⅝	9. 3⅞	3. 3⅝	10. 4½	3. 7⅝	11. 5	3. 11⅝	12. 5⅝
2. 11¾	9. 4¼	3. 3¾	10. 4⅞	3. 7¾	11. 5⅜	3. 11¾	12. 6
2. 11⅞	9. 4⅝	3. 3⅞	11. 5¼	3. 7⅞	11. 5¾	3. 11⅞	12. 6⅜
3. 0	9. 5	3. 4	10. 5⅝	3. 8	11. 6¼	4. 0	12. 6¾
3. 0⅛	9. 5½	3. 4⅛	10. 6	3. 8⅛	11. 6⅝	4. 0⅛	12. 7⅛
3. 0¼	9. 5⅞	3. 4¼	10. 6⅜	3. 8¼	11. 7	4. 0¼	12. 7½
3. 0⅜	9. 6¼	3. 4⅜	10. 6⅞	3. 8⅜	11. 7⅜	4. 0⅜	12. 7⅞
3. 0½	9. 6⅝	3. 4½	10. 7¼	3. 8½	11. 7¾	4. 0½	12. 8⅜
3. 0⅝	9. 7	3. 4⅝	10. 7⅝	3. 8⅝	11. 8⅛	4. 0⅝	12. 8¾
3. 0¾	9. 7⅜	3. 4¾	10. 8	3. 8¾	11. 8½	4. 0¾	12. 9⅛
3. 0⅞	9. 7⅞	3. 4⅞	10. 8⅜	3. 8⅞	11. 8⅞	4. 0⅞	12. 9½

TABLE NO. 4.– 4 ft. 1 in to 5 ft 4⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
4.1	12.9⅞	4.5	13.10½	4.9	14.11	5.1	15.11⅝
4.1⅛	12.10⅜	4.5⅛	13.10⅞	4.9⅛	14.11½	5.1⅛	16.0
4.1¼	12.11¾	4.5¼	13.11¼	4.9¼	14.11⅞	5.1¼	16.0⅜
4.1⅜	12.11⅛	4.5⅜	13.11⅝	4.9⅜	15.0¼	5.1⅜	16.0¾
4.1½	11.11½	4.5½	14.0	4.9½	15.0⅝	5.1½	16.1⅛
4.1⅝	12.11⅞	4.5⅝	14.0⅜	4.9⅝	15.1	5.1⅝	16.1⅝
4.1¾	13.0¼	4.5¾	14.0⅞	4.9¾	15.1⅜	5.1¾	16.2
4.1⅞	13.0⅝	4.5⅞	14.1¼	4.9⅞	15.1⅞	5.1⅞	16.2⅜
4.2	13.1	4.6	14.1⅝	4.10	15.2¼	5.2	16.2¾
4.2⅛	13.1½	4.6⅛	14.2	4.10⅛	15.2⅝	5.2⅛	16.3⅛
4.2¼	13.1⅞	4.6¼	14.2⅜	4.10¼	15.3	5.2¼	16.3½
4.2⅜	13.2¼	4.6⅜	14.2¾	4.10⅜	15.3⅜	5.2⅜	16.3⅞
4.2½	13.2⅝	4.6½	14.3⅛	4.10½	15.3¾	5.2½	16.4⅜
4.2⅝	13.3	4.6⅝	14.3½	4.10⅝	15.4⅛	5.2⅝	16.4¾
4.2¾	13.3⅜	4.6¾	14.4	4.10¾	15.4½	5.2¾	16.5⅛
4.2⅞	13.3¾	4.6⅞	14.4⅜	4.10⅞	15.4⅞	5.2⅞	16.5½
4.3	13.4¼	4.7	14.4¾	4.11	15.5⅜	5.3	16.5⅞
4.3⅛	13.4⅝	4.7⅛	14.5⅛	4.11⅛	15.5¾	5.3⅛	16.6¼
4.3¼	13.5	4.7¼	14.5½	4.11¼	15.6⅛	5.3¼	16.6⅝
4.3⅜	13.5⅜	4.7⅜	14.5⅞	4.11⅜	15.6½	5.3⅜	16.7
4.3½	13.5¾	4.7½	14.6⅜	4.11½	15.6⅞	5.3½	16.7½
4.3⅝	13.6⅛	4.7⅝	14.6¾	4.11⅝	15.7¼	5.3⅝	16.7⅞
4.3¾	13.6½	4.7¾	14.7⅛	4.11¾	15.7¾	5.3¾	16.8¼
4.3⅞	13.7	4.7⅞	14.7½	4.11⅞	15.8⅛	5.3⅞	16.8⅝
4.4	13.7⅜	4.8	14.7⅞	5.0	15.8½	5.4	16.9
4.4⅛	13.7¾	4.8⅛	14.8¼	5.0⅛	15.8⅞	5.4⅛	16.9⅜
4.4¼	13.8⅛	4.8¼	14.8¾	4.0¼	15.9¼	5.4¼	16.9⅞
4.4⅜	13.8½	4.8⅜	14.9⅛	5.0⅜	15.9⅝	5.4⅜	16.10¼
4.4½	13.8⅞	4.8½	14.9½	5.0½	15.10	5.4½	16.10⅝
4.4⅝	13.9¼	4.8⅝	14.9⅞	5.0⅝	15.10⅜	5.4⅝	16.11
4.4¾	13.9⅝	4.8¾	14.10¼	5.0¾	15.10⅞	5.4¾	16.11⅜
4.4⅞	13.10⅛	4.8⅞	14.10⅝	5.0⅞	15.11¼	5.4⅞	16.11¾

TABLE NO 5. 5 ft. 5 in. to 6 ft. 8⅞ in.

DIAM.		CIR.		DIAM.		CIR.		DIAM.		CIR.		DIAM.		CIR.	
FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.
5	5	17	0⅛	5	9	18	0¾	6	1	19	1⅜	6	5	20	1⅞
5	5⅛	17	0⅝	5	9⅛	18	1⅛	6	1⅛	19	1¾	6	5⅛	20	2¼
5	5¼	17	1	5	9¼	18	1½	6	1¼	19	2⅛	6	5¼	20	2⅝
5	5⅜	17	1⅜	5	9⅜	18	1⅞	6	1⅜	19	2½	6	5⅜	20	3
5	5½	17	1¾	5	9½	18	2⅜	6	1½	19	2⅞	6	5½	20	3½
5	5⅝	17	2⅛	5	9⅝	18	2¾	6	1⅝	19	3¼	6	5⅝	20	3⅞
5	5¾	17	2½	5	9¾	18	3⅛	6	1¾	19	3⅝	6	5¾	20	4¼
5	5⅞	17	2⅞	5	9⅞	18	3½	6	1⅞	19	4	6	5⅞	20	4⅝
5	6	17	3⅜	5	10	18	3⅞	6	2	19	4½	6	6	20	5
5	6⅛	17	3¾	5	10⅛	18	4¼	6	2⅛	19	4⅞	6	6⅛	20	5⅜
5	6¼	17	4⅛	5	10¼	18	4⅝	6	2¼	19	5¼	6	6¼	20	5⅞
5	6⅜	17	4½	6	10⅜	18	5	6	2⅜	19	5⅝	6	6⅜	20	6¼
5	6½	17	4⅞	5	10½	18	5½	6	2½	19	6	6	6½	20	6⅝
5	6⅝	17	5¼	5	10⅝	18	5⅞	6	2⅝	19	6⅜	6	6⅝	20	7
5	6¾	17	5⅝	5	10¾	18	6¼	6	2¾	19	6⅞	6	6¾	20	7⅜
5	6⅞	17	6	5	10⅞	18	6⅝	6	2⅞	19	7¼	6	6⅞	20	7¾
5	7	17	6½	5	11	18	7	6	3	19	7⅝	6	7	20	8⅛
5	7⅛	17	6⅞	5	11⅛	18	7⅜	6	3⅛	19	8	6	7⅛	20	8½
5	7¼	17	7¼	5	11¼	18	7⅞	6	3¼	19	8⅜	6	7¼	20	9
5	7⅜	17	7⅝	5	11⅜	18	8¼	6	3⅜	19	8¾	6	7⅜	20	9⅜
5	7½	17	8	5	11½	18	8⅝	6	3½	19	9⅛	6	7½	20	9¾
5	7⅝	17	8⅜	5	11⅝	18	9	6	3⅝	19	9⅝	6	7⅝	20	10⅛
5	7¾	17	8⅞	5	11¾	18	9⅜	6	3¾	19	10	6	7¾	20	10½
5	7⅞	17	9¼	5	11⅞	18	9¾	6	3⅞	19	10⅜	6	7⅞	20	1 ⅞
5	8	17	9⅝	6	0	18	10⅛	6	4	19	10¾	6	8	20	11⅜
5	8⅛	17	10	6	0⅛	18	10½	6	4⅛	19	11⅛	6	8⅛	20	11¾
5	8¼	17	10⅜	6	0¼	18	11	6	4¼	19	11½	6	8¼	21	0⅛
5	8⅜	17	10¾	6	0⅜	18	11⅜	6	4⅜	19	11⅞	6	8⅜	21	0½
5	8½	17	11⅛	6	0½	18	11¾	6	4½	20	0⅜	6	8½	21	0⅞
5	8⅝	17	11½	6	0⅝	19	0⅛	6	4⅝	20	0¾	6	8⅝	21	1¼
5	8¾	18	0	6	0¾	19	0½	6	4¾	20	1⅛	6	8¾	21	1⅝
5	8⅞	18	0⅜	6	0⅞	19	0⅞	6	4⅞	20	1½	6	8⅞	21	2

TABLE NO. 6.—6 ft. 9 in to 8 ft. 8⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
6. 9	21. 2½	7.1	22. 3	7.5	23. 3⅝	7 9	24. 4⅛
6. 9⅛	21. 2⅞	7 1⅛	22. 3⅜	7.5⅛	23. 4	7 9⅛	24 4½
6. 9¼	21. 3¼	7.1¼	22. 3⅞	7.5¼	23. 4⅜	7 9¼	24. 4⅞
6. 9⅜	21. 3⅝	7.1⅜	22. 4¼	7.5⅜	23. 4¾	7 9⅜	24 5⅜
6. 9½	21. 4	7.1½	22. 4⅝	7.5½	23. 5⅛	7 9½	24 5¾
6. 9⅝	21. 4⅜	7.1⅝	22 5	7.5⅝	23. 5½	7 9⅝	24 6⅛
6. 9¾	21. 4¾	7.1¾	22. 5⅜	7.5¾	23. 6	7 9¾	24 6½
6. 9⅞	21. 5¼	7.1⅞	22 5¾	7.5⅞	23. 6⅜	7 9⅞	24 6⅞
6.10	21. 5½	7.2	22. 6⅛	7.6	23 6¾	7 10	24. 7¼
6.10⅛	21. 6	7.2⅛	22. 6½	7.6⅛	23. 7⅛	7 10⅛	24. 7⅝
6.10¼	21. 6⅜	7.2¼	22. 7	7.6¼	23. 7½	7 10¼	24. 8
6.10⅜	21. 6¾	7.2⅜	22. 7⅜	7.6⅜	23. 7⅞	7 10⅜	24. 8½
6.10½	21. 7⅛	7 2½	22. 7¾	7.6½	23. 8¼	7 10½	24. 8⅞
6.10⅝	21. 7⅝	7 2⅝	22. 8⅛	7.6⅝	23. 8¾	7 10⅝	24. 9¼
6.10¾	21. 8	7.2¾	22. 8½	7.6¾	23. 9⅛	7 10¾	24. 9⅝
6.10⅞	21. 8⅜	7.2⅞	22. 8⅞	7.6⅞	23. 9½	7 10⅞	24.10
6.11	21. 8¾	7.3	22 9¼	7.7	23. 9⅞	7 11	24.10½
6.11⅛	21. 9⅛	7.3⅛	22. 9¾	7.7⅛	23.10¼	7 11⅛	24.10⅞
6.11¼	21. 9½	7.3¼	22 10⅛	7.7¼	23.10⅝	7.11¼	24.11¼
6.11⅜	21. 9⅞	7.3⅜	22 10½	7.7⅜	23.11	7.11⅜	24.11⅝
6.11½	21.10⅜	7.3½	22 10⅞	7.7½	23.11½	7.11½	25. 0
6.11⅝	21.10¾	7.3⅝	22.11¼	7.7⅝	23.11⅞	7.11⅝	25. 0⅜
6.11¾	21.11⅛	7.3¾	22.11⅝	7.7¾	24. 0¼	7.11¾	25. 0¾
6.11⅞	21.11⅝	7.3⅞	23. 0	7.7⅞	24 0⅝	7 11⅞	25. 1¼
7. 0	22. 0	7.4	23. 0½	7.8	24. 1	8. 0	25. 1⅝
7. 0⅛	22. 0¼	7.4⅛	23. 0⅞	7.8⅛	24. 1⅜	8. 0⅛	25. 2
7. 0¼	22. 0⅝	7.4¼	23. 1¼	7.8¼	24. 1¾	8. 0¼	25. 2⅜
7. 0⅜	22. 1	7.4⅜	23. 1⅝	7.8⅜	24. 2¼	8. 0⅜	25. 2¾
7. 0½	22. 1½	7.4½	23. 2	7.8½	24. 2⅝	8. 0½	25. 3⅛
7. 0⅝	22. 1⅞	7.4⅝	23. 2⅜	7.8⅝	24. 3	8. 0⅝	25. 3½
7. 0¾	22. 2¼	7.4¾	23. 2¾	7.8¾	24. 3⅜	8. 0¾	25. 3⅞
7. 0⅞	22. 2⅝	7.4⅞	23. 3¼	7.8⅞	24. 3¾	8. 0⅞	25. 4⅜

TABLE NO. 7.—8 ft. 1 in. to 9 ft. 4⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
8. 1	25. 4¾	8. 5	26. 5¼	8. 9	27. 5⅞	9. 1	28. 6⅜
8. 1⅛	25. 5⅛	8. 5⅛	26. 5⅝	8. 9⅛	27. 6¼	9. 1⅛	28. 6⅞
8. 1¼	25. 5½	8. 5¼	26. 6	8. 9¼	27. 6⅝	9. 1¼	28. 7¼
8. 1⅜	25. 5⅞	8. 5⅜	26. 6½	8. 9⅜	27. 7	9. 1⅜	28. 7⅝
8. 1½	25. 6¼	8. 5½	26. 6⅞	8. 9½	27. 7⅜	9. 1½	28. 8
8. 1⅝	25. 6⅝	8. 5⅝	26. 7¼	8. 9⅝	27. 7⅞	9. 1⅝	28. 8⅜
8. 1¾	25. 7	8. 5¾	26. 7⅝	8. 9¾	27. 8¼	9. 1¾	28. 8⅞
8. 1⅞	25. 7½	8. 5⅞	26. 8	8. 9⅞	27. 8⅝	9. 1⅞	28. 9⅛
8. 2	25. 7⅞	8. 6	26. 8⅜	8. 10	27. 9	9. 2	28. 9⅝
8. 2⅛	25. 8¼	8. 6⅛	26. 8⅞	8. 10⅛	27. 9⅜	9. 2⅛	28. 10
8. 2¼	25. 8⅝	8. 6¼	26. 9¼	8. 10¼	27. 9¾	9. 2¼	28. 10⅜
8. 2⅜	25. 9	8. 6⅜	26. 9⅝	8. 10⅜	27. 10⅛	9. 2⅜	28. 10¾
8. 2½	25. 9½	8. 6½	26. 10	8. 10½	27. 10⅝	9. 2½	28. 11⅛
8. 2⅝	25. 9⅞	8. 6⅝	26. 10⅜	8. 10⅝	27. 11	9. 2⅝	28. 11½
8. 2¾	25. 10¼	8. 6¾	26. 10¾	8. 10¾	27. 11⅜	9. 2¾	28. 11⅞
8. 2⅞	25. 10⅝	8. 6⅞	26. 11⅛	8. 10⅞	27. 11¾	9. 2⅞	29. 0⅜
8. 3	25. 11	8. 7	26. 11½	8. 11	28. 0⅛	9. 3	29. 0¾
8. 3⅛	25. 11⅜	8. 7⅛	27. 0	8. 11⅛	28. 0½	9. 3⅛	29. 1⅛
8. 3¼	25. 11¾	8. 7¼	27. 0⅜	8. 11¼	28. 0⅞	9. 3¼	29. 1½
8. 3⅜	26. 0⅛	8. 7⅜	27. 0¾	8. 11⅜	28. 1⅜	9. 3⅜	29. 1⅞
8. 3½	26. 0⅝	8. 7½	27. 1⅛	8. 11½	28. 1¾	9. 3½	29. 2¼
8. 3⅝	26. 1	8. 7⅝	27. 1½	8. 11⅝	28. 2⅛	9. 3⅝	29. 2⅝
8. 3¾	26. 1⅜	8. 7¾	27. 1⅞	8. 11¾	28. 2½	9. 3¾	29. 3
8. 3⅞	26. 1¾	8. 7⅞	27. 2⅜	8. 11⅞	28. 2⅞	9. 3⅞	29. 3½
8. 4	26. 2⅛	8. 8	27. 2¾	9. 0	28. 3¼	9. 4	29. 3⅞
8. 4⅛	26. 2½	8. 8⅛	27. 3⅛	9. 0⅛	28. 3⅝	9. 4⅛	29. 4¼
8. 4¼	26. 2⅞	8. 8¼	27. 3½	9. 0¼	28. 4	9. 4¼	29. 4⅝
8. 4⅜	26. 3⅜	8. 8⅜	27. 3⅞	9. 0⅜	28. 4½	9. 4⅜	29. 5
8. 4½	26. 3¾	8. 8½	27. 4¼	9. 0½	28. 4⅞	9. 4½	29. 5⅜
8. 4⅝	26. 4⅛	8. 8⅝	27. 4⅝	9. 0⅝	28. 5¼	9. 4⅝	29. 5¾
8. 4¾	26. 4½	8. 8¾	27. 5	9. 0¾	28. 5⅝	9. 4¾	29. 6¼
8. 4⅞	26. 4⅞	8. 8⅞	27. 5½	9. 0⅞	28. 6	9. 4⅞	29. 6⅝

TABLE NO. 8—9 ft. 5 in. to 10 ft. 8⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
9.5	29. 7	9. 9	30. 7½	10. 1	31. 8⅛	10.5	32. 8¾
9.5⅛	29. 7⅜	9. 9⅛	30. 7⅞	10. 1⅛	31. 8½	10.5⅛	32. 9
9.5¼	29. 7¾	9. 9¼	30. 8⅜	10. 1¼	31 8⅞	10.5¼	32. 9½
9.5⅜	29. 8⅛	9 9⅜	30. 8¾	10. 1⅜	31. 9¼	10.5⅜	32. 9⅞
9.5½	29 8½	9. 9½	30. 9⅛	10. 1½	31. 9¾	10.5½	32.10¼
9.5⅝	29. 9	9. 9⅝	30. 9½	11. 1⅝	31.10	10.5⅝	32.10⅝
9.5¾	29. 9⅜	9. 9¾	30. 9⅞	10. 1¾	31.10½	10 5¾	32.11
9.5⅞	29. 9¾	9. 9⅞	30 10¼	10. 1⅞	31.10⅞	10 5⅞	32.11⅜
9 6	29.10⅛	9.10	30.10⅝	10. 2	31.11¼	10.6	32.11⅞
9.6⅛	29 10½	9.10⅛	30.11⅛	10. 2⅛	31.11⅝	10.6⅛	33. 0¼
9.6¼	29.10⅞	9.10¼	30.11½	10. 2¼	32. 0	10.6¼	33 0⅝
9 6⅜	29.11⅜	9.10⅜	30.11⅞	10. 2⅜	32. 0½	10.6⅜	33. 1
9.6½	29.11⅝	9.10½	31 0¼	10 2½	32. 0⅞	10.6½	33. 1⅜
9.6⅝	30. 0	9.10⅝	31. 0⅝	10. 2⅝	32. 1¼	10.6⅝	33. 1¾
9.6¾	30 0½	9.10¾	31. 1	10 2¾	32. 1⅝	10 6¾	33. 2⅛
9.6⅞	30. 0⅞	9.10⅞	31. 1⅜	10. 2⅞	32. 2	10.6⅞	33. 2⅝
9.7	30. 1¼	9.11	31. 1⅞	10. 3	32. 2⅜	10.7	33. 3
9.7⅛	30. 1⅝	9.11⅛	31. 2¼	10. 3⅛	32. 2¾	10.7⅛	33. 3⅜
9.7¼	30. 2	9.11¼	31. 2⅝	10. 3¼	32. 3¼	10.7¼	33. 3¾
9.7⅜	30. 2½	9.11⅜	31. 3	10. 3⅜	32. 3⅝	10.7⅜	33. 4⅛
9.7½	30. 2⅞	9.11½	31. 3⅜	10. 3½	32. 4	10.7½	33. 4½
9.7⅝	30. 3¼	9 11⅝	31. 3¾	10. 3⅝	32. 4⅜	10 7⅝	33. 4⅞
9.7¾	30. 3⅝	9.11¾	31. 4¼	10. 3¾	32. 4¾	10.7¾	33. 5⅜
9.7⅞	30. 4	9.11⅞	31 4⅝	10. 3⅞	32. 5⅛	10.7⅞	33. 5¾
9.8	30. 4⅜	10. 0	31. 5	10. 4	32. 5½	10.8	33. 6⅛
9 8⅛	30. 4¾	10. 0⅛	31. 5⅜	10. 4⅛	32. 6	10.8⅛	33. 6½
9.8¼	30 5¼	10. 0¼	31. 5¾	10. 4¼	32. 6⅜	10.8¼	33. 6⅞
9.8⅜	30 5⅝	10. 0⅜	31 6⅛	10. 4⅜	32. 6¾	10.8⅜	33. 7¼
9.8½	30 6	10. 0½	31. 6½	10 4½	32. 7⅛	10 8½	33. 7⅝
9.8⅝	30 6⅜	10. 0⅝	31. 7	10. 4⅝	32. 7½	10.8⅝	33. 8
9.8¾	30. 6¾	10. 0¾	31 7⅜	10. 4¾	32. 7⅞	10.8¾	33. 8½
9.8⅞	30. 7⅛	10. 0⅞	31. 7¾	10. 4⅞	32. 8¼	10.8⅞	33. 8⅞

TABLE NO. 9.—10 ft. 9 in. to 12 ft. 0⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
10. 9	33. 9¼	11. 1	34. 9¾	11. 5	35. 10⅜	11. 9	36. 11
10. 9⅛	33. 9⅝	11. 1⅛	34. 10¼	11. 5⅛	35. 10¾	11. 9⅛	36. 11⅜
10. 9¼	33. 10	11. 1¼	34. 10⅝	11. 5¼	35. 11⅛	11. 9¼	36. 11¾
10. 9⅜	33. 10⅜	11. 1⅜	34. 11	11. 5⅜	35. 11½	11. 9⅜	37. 0⅛
10. 9½	33. 10⅞	11. 1½	34. 11⅜	11. 5½	36. 0	11. 9½	37. 0½
10. 9⅝	33. 11¼	11. 1⅝	34. 11¾	11. 5⅝	36. 0⅜	11. 9⅝	37. 0⅞
10. 9¾	33. 11⅝	11. 1¾	35. 0⅛	11. 5¾	36. 0¾	11. 9¾	37. 1⅜
10. 9⅞	34. 0	11. 1⅞	35. 0½	11. 5⅞	36. 1⅛	11. 9⅞	37. 1¾
10. 10	34. 0⅜	11. 2	35. 1	11. 6	36. 1½	11. 10	37. 2⅛
10. 10⅛	34. 0¾	11. 2⅛	35. 1⅜	11. 6⅛	36. 1⅞	11. 10⅛	37. 2½
10. 10¼	34. 1⅛	11. 2¼	35. 1¾	11. 6¼	36. 2⅜	11. 10¼	37. 2⅞
10. 10⅜	34. 1⅝	11. 2⅜	35. 2⅛	11. 6⅜	36. [illegible]¾	11. 10⅜	37. 3¼
10. 10½	34. 2	11. 2½	35. 2½	11. 6½	36. 3⅛	11. 10½	37. 3⅝
10. 10⅝	34. 2⅜	11. 2⅝	35. 2⅞	11. 6⅝	36. 3½	11. 10⅝	37. 4
10. 10¾	34. 2¾	11. 2¾	35. 3⅜	11. 6¾	36. 3⅞	11. 10¾	37. 4½
10. 10⅞	34. 3⅛	11. 2⅞	35. 3¾	11. 6⅞	36. 4¼	11. 10⅞	37. 4⅞
10. 11	34. 3½	11. 3	35. 4⅛	11. 7	36. 4⅝	11. 11	47. 5¼
10. 11⅛	34. 3⅞	11. 3⅛	35. 4½	11. 7⅛	36. 5	11. 11⅛	37. 5⅝
10. 11¼	34. 4⅜	11. 3¼	35. 4⅞	11. 7¼	36. 5½	11. 11¼	37. 6
10. 11⅜	34. 4¾	11. 3⅜	35. 5¼	11. 7⅜	36. 5⅞	11. 11⅜	37. 6⅜
10. 11½	34. 5⅛	11. 3½	35. 5⅝	11. 7½	36. 6¼	11. 11½	37. 6⅞
10. 11⅝	34. 5½	11. 3⅝	35. 6	11. 7⅝	36. 6⅝	11. 11⅝	37. 7¼
10. 11¾	34. 5⅞	11. 3¾	35. 6½	11. 7¾	36. 7	11. 11¾	37. 7⅝
10. 11⅞	34. 6¼	11. 3⅞	35. 6⅞	11. 7⅞	36. 7⅜	11. 11⅞	37. 8
11. 0	34. 6⅝	11. 4	35. 7¼	11. 8	36. 7¾	12. 0	37. 8⅜
11. 0⅛	34. 7	11. 4⅛	35. 7⅝	11. 8⅛	36. 8⅛	12. 0⅛	37. 8¾
11. 0¼	34. 7½	11. 4¼	35. 8	11. 8¼	36. 8½	12. 0¼	37. 9⅛
11. 0⅜	34. 7⅞	11. 4⅜	35. 8⅜	11. 8⅜	36. 8⅞	12. 0⅜	37. 9½
11. 0½	34. 8¼	11. 4½	35. 8⅞	11. 8½	36. 9¼	12. 0½	37. 10
11. 0⅝	34. 8⅝	11. 4⅝	35. 9¼	11. 8⅝	36. 9⅝	12. 0⅝	37. 10⅜
11. 0¾	34. 9	11. 4¾	35. 9⅝	11. 8¾	36. 10⅛	12. 0¾	37. 10¾
11. 0⅞	34. 9⅜	11. 4⅞	35. 10	11. 8⅞	36. 10½	12. 0⅞	37. 11⅛

TABLE NO. 10.—12 ft. 1 in to 13 ft. 4⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
12.1	37.11½	12.5	39. 0⅛	12. 9	40. 0⅝	13.1	41. 1¼
12.1⅛	38. 0	12.5⅛	39. 0½	12. 9⅛	40. 1	13.1⅛	41. 1⅝
12.1¼	38. 0⅜	12.5¼	39. 0⅞	12. 9¼	40. 1⅜	13.1¼	41. 2
12.1⅜	38. 0¾	12.5⅜	39. 1¼	12. 9⅜	40. 1⅞	13 1⅜	41. 2⅜
12.1½	38. 1⅛	12.5½	39. 1⅝	12. 9½	40. 2¼	13 1½	41. 2¾
12.1⅝	38. 1½	12.5⅝	39. 2	12. 9⅝	40. 2⅝	13.1⅝	41. 3⅛
12.1¾	38. 1⅞	12.5¾	39. 2⅜	12. 9¾	40. 3	13.1¾	41. 3⅝
12.1⅞	38. 2¼	12.5⅞	39. 2⅞	12. 9⅞	40. 3⅜	13.1⅞	41. 4
12.2	38. 2⅝	12.6	39. 3¼	12.10	40. 3¾	13.2	41. 4⅜
12.2⅛	38. 3	12.6⅛	39. 3⅝	12.10⅛	40. 4⅛	13.2⅛	41. 4¾
12.2¼	38. 3½	12.6¼	39. 4	12.10¼	40. 4⅝	13.2¼	41. 5⅛
12.2⅜	38. 3⅞	12.6⅜	39. 4⅜	12.10⅜	40. 5	13.2⅜	41. 5½
12.2½	38. 4¼	12.6½	39. 4¾	12.10½	40. 5⅜	13.2½	41. 5⅞
12.2⅝	38. 4⅝	12 6⅝	39. 5¼	12.10⅝	40. 5¾	13.2⅝	41. 6¼
12.2¾	38. 5	12.6¾	39. 5⅝	12.10¾	40. 6⅛	13.2¾	41. 6¾
12.2⅞	38. 5⅜	12.6⅞	39. 6	12.10⅞	40. 6½	13.2⅞	41. 7⅛
12.3	38. 5¾	12.7	39 6⅜	12.11	40. 6⅞	13.3	41. 7½
12.3⅛	38. 6¼	12.7⅛	36. 6¾	12.11⅛	40. 7⅜	13.3⅛	41. 7⅞
12.3¼	38. 6⅝	12.7¼	39. 7⅛	12.11¼	40. 7¾	13.3¼	41. 8¼
12.3⅜	38. 7	12.7⅜	39. 7½	12.11⅜	40. 8⅛	13.3⅜	41. 8⅝
12.3½	38. 7⅜	12.7½	39. 7⅞	12.11½	40. 8½	13.3½	41. 9
12.3⅝	38. 7¾	12.7⅝	39. 8⅜	12.11⅝	40. 8⅞	13.3⅝	41. 9½
12.3¾	38. 8⅛	12.7¾	39. 8¾	12.11¾	40. 9¼	13.3¾	41. 9⅞
12.3⅞	38. 8½	12.7⅞	39. 9⅛	12.11⅞	40. 9⅝	13.3⅞	41.10¼
12.4	38. 9	12.8	39. 9½	13. 0	40 10	13.4	41.10⅝
12.4⅛	38. 9⅜	12.8⅛	39. 9⅞	13. 0⅛	40.10⅜	13 4⅛	41.11
12.4¼	38. 9¾	12.8¼	39.10¼	13. 0¼	40.10⅞	13.4¼	41.11⅜
12.4⅜	38.10⅛	12.8⅜	39.10⅝	13. 0⅜	40.11¼	13.4⅜	41.11¾
12.4½	38.10½	12.8½	39.11	13. 0½	40.11⅝	13.4½	42. 0¼
12.4⅝	38.10⅞	12.8⅝	39.11½	13. 0⅝	41. 0	13 4⅝	42. 0⅝
12.4¾	38.11¼	12.8¾	39.11⅞	13. 0¾	41. 0⅜	13.4¾	42. 1
12.4⅞	38.11¾	12.8⅞	40. 0¼	13. 0⅞	41. 0⅞	13.4⅞	42. 1⅜

TABLE NO. 11.—13 ft. 5 in. to 14 ft. 8⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
13.5	42. 1⅞	13. 9	43. 2⅜	14.1	44. 2⅞	14.5	45. 3½
13.5⅛	42. 2⅛	13. 9⅛	43. 2¾	14.1⅛	44. 3¼	14.5⅛	45. 3⅞
13.5¼	42. 2½	13. 9¼	43. 3⅛	14.1¼	44. 3¾	14.5¼	45. 4¼
13.5⅜	42. 3	13. 9⅜	43. 3½	14.1⅜	44. 4⅛	44.5⅜	45. 4⅝
13.5½	42. 3⅜	13. 9½	43 3⅞	14.1½	44. 4½	14.5½	45. 5
13.6⅝	42. 3¾	13. 9⅝	43. 4¼	14.1⅝	44. 4⅞	14.5⅝	45. 5⅜
13.5¾	42. 4⅛	13. 9¾	43. 4¾	14.1¾	44. 5¼	14.5¾	45. 5⅞
13.5⅞	42. 4½	13. 9⅞	43. 5⅛	14.1⅞	44. 5⅝	14.5⅞	45. 6¼
13.6	42. 4⅞	13.10	43. 5½	14.2	44. 6	14.6	45. 6⅝
13.6⅛	42. 5¼	13.10⅛	43. 5⅞	14.2⅛	44. 6⅜	14.6⅛	45. 7
13.6¼	42. 5¾	13.10¼	43. 6¼	14.2¼	44. 6⅞	14.6¼	45. 7⅜
13.6⅜	42. 6⅛	13.10⅜	43. 6⅝	14.2⅜	44. 7¼	14.6⅜	45. 7¾
13.6½	42. 6½	13.10½	43. 7	14.2½	44. 7⅝	14.6½	45. 8¼
13.6⅝	42. 6⅞	13.10⅝	43. 7½	14.2⅝	44. 8	14.6⅝	45. 8⅝
13.6¾	42. 7¼	13.10¾	43. 7⅞	14.2¾	44. 8⅜	14.6¾	45. 9
13.6⅞	42. 7⅝	13.10⅞	43. 8¼	14.2⅞	44. 8¾	14.6⅞	45. 9⅜
13.7	42. 8	13.11	43. 8⅝	14.3	44. 9⅛	14.7	45. 9¾
13.7⅛	42. 8½	13.11⅛	43. 9	14.3⅛	44. 9½	14.7⅛	45.10⅛
13.7¼	42. 8⅞	13.11¼	43. 9⅜	14.3¼	44.10	14.7¼	45.10½
13.7⅜	42. 9¼	13.11⅜	43. 9¾	14.3⅜	44.10⅜	14.7⅜	45.10⅞
13.7½	42. 9⅝	13.11½	43.10¼	14.3½	44.10¾	14.7½	45.11⅜
13.7⅝	42.10	13.11⅝	43.10⅝	14.3⅝	44.11⅛	14.7⅝	45.11¾
13.7¾	42.10⅜	13.11¾	43.11	14.3¾	44.11½	14.7¾	46. 0⅛
13.7⅞	42.10⅞	13.11⅞	43.11⅜	14.3⅞	44.11⅞	14.7⅞	46. 0½
13.8	42.11¼	14. 0	43.11¾	14.4	45. 0⅜	14.8	46. 0⅞
13.8⅛	42.11⅝	14. 0⅛	44. 0⅛	14.4⅛	45. 0¾	14.8⅛	46. 1¼
13.8¼	43. 0	14. 0¼	44. 0½	14.4¼	45. 1⅛	14.8¼	46. 1¾
13.8⅜	43. 0⅜	14. 0⅜	44. 0⅞	14.4⅜	45. 1½	14.8⅜	46. 2⅛
13.8½	43. 0¾	14. 0½	44. 1⅜	14.4½	45. 1⅞	14.8½	46. 2½
13.8⅝	43. 1⅛	14. 0⅝	44. 1¾	14.4⅝	45. 2¼	14.8⅝	46. 2⅞
13.8¾	43. 1½	14. 0¾	44. 2⅛	14.4¾	45. 2¾	14.8¾	46. 3½
13.8⅞	43. 1⅞	14. 0⅞	44. 2½	14.4⅞	45. 3⅛	14.8⅞	46. 3⅞

TABLE NO. 12.—14 ft. 9 in. to 16 ft. 0⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
14. 9	46. 4	15. 1	47. 4⅝	15. 5	48. 5⅛	15. 9	49. 5¾
14. 9⅛	46. 4⅜	15. 1⅛	47. 5	15. 5⅛	48. 5⅝	15. 9⅛	49. 6⅛
14. 9¼	46. 4⅞	15. 1¼	47. 5⅜	15. 5¼	48. 6	15. 9¼	49. 6½
14. 9⅜	46. 5¼	15. 1⅜	47. 5¾	15. 5⅜	48. 6⅜	15. 9⅜	49. 6⅞
14. 9½	46. 5⅝	15. 1½	47. 6¼	15. 5½	48. 6¾	15. 9½	49. 7⅜
14. 9⅝	46. 6	15. 1⅝	47. 6⅝	15. 5⅝	48. 7⅛	15. 9⅝	49. 7¾
14. 9¾	46. 6⅜	15. 1¾	47. 7	15. 5¾	48. 7½	15. 9¾	49. 8⅛
14. 9⅞	46. 6¾	15. 1⅞	47. 7⅜	15. 5⅞	48. 7⅞	15. 9⅞	49. 8½
14.10	46. 7⅛	15. 2	47. 7¾	15. 6	48. 8⅜	15.10	49. 8⅞
14.10⅛	46. 7½	15. 2⅛	47. 8⅛	15. 6⅛	48. 8¾	15.10⅛	49. 9¼
14.10¼	46. 7⅞	15. 2¼	47. 8½	15. 6¼	48. 9⅛	15.10¼	49. 9⅝
14.10⅜	46. 8⅜	15. 2⅜	47. 9	15. 6⅜	48. 9½	15.10⅜	49.10
14.10½	46. 8¾	15. 2½	47. 9⅜	15. 6½	48. 9⅞	15.10½	49.10½
14.10⅝	46. 9⅛	15. 2⅝	47. 9¾	15. 6⅝	48.10¼	15.10⅝	49.10⅞
14.10¾	46. 9½	15. 2¾	47.10⅛	15. 6¾	48.10⅝	15.10¾	49.11¼
14.10⅞	46. 9⅞	15. 2⅞	47.10½	15. 6⅞	48.11	15.10⅞	49.11⅝
14.11	46.10⅜	15. 3	47.10⅞	15. 7	48.11½	15.11	50. 0
14.11⅛	46.10¾	15. 3⅛	47.11¼	15. 7⅛	48.11⅞	15.11⅛	50. 0½
14.11¼	46.11⅛	15. 3¼	47.11¾	15. 7¼	49. 0¼	15.11¼	50. 0⅞
14.11⅜	46.11½	15. 3⅜	48. 0	15. 7⅜	49. 0⅝	15.11⅜	50. 1¼
14.11½	46.11⅞	15. 3½	48. 0½	15. 7½	49. 1	15.11½	50. 1⅝
14.11⅝	47. 0¼	15. 3⅝	48. 0⅞	15. 7⅝	49. 1⅜	15.11⅝	50. 2
14.11¾	47. 0¾	15. 3¾	48. 1¼	15. 7¾	49. 1¾	15.11¾	50. 2⅜
14.11⅞	47. 1	15. 3⅞	48. 1⅝	15. 7⅞	49. 2¼	15.11⅞	50. 2¾
15. 0	47. 1½	15. 4	48. 2	15. 8	49. 2⅝	16. 0	50. 3⅛
15. 0⅛	47. 1⅞	15. 4⅛	48. 2⅜	15. 8⅛	49. 3	16. 0⅛	50. 3½
15. 0¼	47. 2¼	15. 4¼	48. 2⅞	15. 8¼	49. 3⅜	16. 0¼	50. 4
15. 0⅜	47. 2⅝	15. 4⅜	48. 3¼	15. 8⅜	49. 3¾	16. 0⅜	50. 4⅜
15. 0½	47. 3	15. 4½	48. 3⅝	15. 8½	49. 4⅛	16. 0½	50. 4¾
15. 0⅝	47. 3⅜	15. 4⅝	48. 4	15. 8⅝	49. 4½	16. 0⅝	50. 5⅛
15. 0¾	47. 3⅞	15. 4¾	48. 4⅜	15. 8¾	49. 5	16. 0¾	50. 5½
15. 0⅞	47. 4¼	15. 4⅞	48. 4¾	15. 8⅞	49. 5⅜	16. 0⅞	50. 5⅞

TABLE NO. 13.—16 ft. 1 in. to 17 ft. 4⅞ in.

DIAM.	CIR.	DIAM.	CIR.	DIAM.	CIR.	DIAM.	CIR.
FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.
16.1	50. 6¼	16.5	51. 6⅞	16. 9	52. 7⅜	17. 1	53. 8
16.1⅛	50. 6¾	16.5⅛	51. 7¼	16. 9⅛	52. 7⅞	17. 1⅛	53. 8⅜
16.1¼	50. 7⅛	16 5¼	51. 7⅝	16. 9¼	52. 8¼	17. 1¼	53. 8¾
16.1⅜	50. 7½	16.5⅜	51. 8	16. 9⅜	52. 8⅝	17. 1⅜	53. 9¼
16.1½	50. 7⅞	16.5½	51. 8⅜	16. 9½	52. 9	17. 1½	53. 9⅝
16.1⅝	50. 8¼	16.5⅝	51. 8⅞	16. 9⅝	52. 9⅜	17. 1⅝	53.10
16.1¾	50. 8⅝	16.5¾	51. 9¼	16. 9¾	52. 9¾	17. 1¾	53.10⅜
16.1⅞	50. 9	16.5⅞	51. 9⅝	16. 9⅞	52.10¼	17. 1⅞	53.10¾
16.2	50. 9½	16.6	51.10	16.10	52.10⅝	17. 2	53.11⅛
16.2⅛	50. 9⅞	16.6⅛	51.10⅜	16.10⅛	52.11	17. 2⅛	53 11½
16.2¼	50.10¼	16.6¼	51.10¾	16.10¼	52.11⅜	17. 2¼	53.11⅞
16.2⅜	50.10⅝	16.6⅜	51.11⅛	16.10⅜	52.11¾	17. 2⅜	54. 0¼
16 2½	50.11	16.6½	51.11⅝	16.10½	53. 0⅛	17. 2½	54. 0¾
16.2⅝	50.11⅜	16.6⅝	52. 0	16.10⅝	53. 0½	17. 2⅝	54. 1⅛
16 2¾	50.11⅞	16.6¾	52. 0⅜	16.10¾	53. 1	17. 2¾	54. 1½
16.2⅞	51. 0¼	16.6⅞	52. 0¾	16.10⅞	53. 1⅜	17. 2⅞	54. 1⅞
16.3	51. 0⅝	16.7	52. 1⅛	16.11	53. 1¾	17. 3	54. 2¼
16 3⅛	51. 1	16 7⅛	52. 1½	16.11⅛	53. 2⅛	17. 3⅛	54. 2⅝
16.3¼	51. 1⅜	16.7¼	52. 2	16.11¼	53. 2½	17. 3¼	54. 3
16 3⅜	51. 1¾	16.7⅜	52. 2⅜	16.11⅜	53. 2⅞	17. 3⅜	54. 3½
16 3½	51. 2⅛	16.7½	52. 2¾	16.11½	53. 3¼	17. 3½	54. 3⅞
16.3⅝	51. 2½	16.7⅝	52. 3⅛	16.11⅝	53. 3⅝	17. 3⅝	54. 4¼
16.3¾	51. 3	16.7¾	52. 3½	16 11¾	53. 4⅛	17. 3¾	54. 4⅝
16.3⅞	51. 3⅜	16.7⅞	52. 3⅞	16.11⅞	53. 4½	17. 3⅞	54. 5
16.4	51. 3¾	16.8	52. 4¼	17. 0	53. 4⅞	17. 4	54 5⅜
16 4⅛	51. 4⅛	16.8⅛	52. 4¾	17. 0⅛	53. 5¼	17. 4⅛	54. 5⅞
16.4¼	51. 4⅝	16.8¼	52. 5⅛	17. 0¼	53. 5⅝	17. 4¼	54 6¼
16.4⅜	61. 5	16.8⅜	52. 5½	17. 0⅜	53. 6	17. 4⅜	54. 6⅝
16.4½	51. 5⅜	16.8½	52. 5⅞	17. 0½	53. 6½	17. 4½	54. 7
16.4⅝	51. 5¾	16.8⅝	52. 6¼	17. 0⅝	53. 6⅞	17. 4⅝	54. 7⅜
16.4¾	51. 6⅛	16.8¾	52. 6⅝	17. 0¾	53. 7¼	17. 4¾	54. 7¾
16 4⅞	51. 6½	16.8⅞	52. 7	17. 0⅞	53. 7⅝	17. 4⅞	54. 8¼

TABLE NO. 14.—17 ft. 5 in. to 18 ft. 8⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.
17.5	54. 8⅝	17. 9	55. 9⅛	18. 1	56. 9¾	18.5	57.10¼
17.5⅛	54. 9	17. 9⅛	55. 9½	18.1⅛	56.10⅛	18.5⅛	57.10⅝
17.5¼	54. 9⅜	17. 9¼	55. 9⅞	18.1¼	56.10½	18.5¼	57.11
17.5⅜	54. 9¾	17. 9⅜	55.10⅜	18.1⅜	56.10⅞	18.5⅜	57.11⅜
17.5½	54.10⅛	17. 9½	55.10¾	18.1½	56.11¼	18.5½	57.11¾
17.5⅝	54.10½	17. 9⅝	55.11⅛	18.1⅝	56.11⅝	18.5⅝	58. 0¼
17.5¾	54.10⅞	17. 9¾	55.11½	18.1¾	57. 0	18.5¾	58. 0⅝
17.5⅞	54.11¼	17. 9⅞	55.11⅞	18.1⅞	57. 0½	18.5⅞	58. 1
17.6	54.11¾	17.10	56. 0¼	18.2	57. 0⅞	18.6	58. 1⅜
17.6⅛	55. 0⅛	17.10⅛	56. 0⅝	18.2⅛	57. 1¼	18.6⅛	58. 1⅞
17.6¼	55. 0½	17.10¼	56. 1	18.2¼	57. 1⅝	18.6¼	58. 2¼
17.6⅜	55. 0⅞	17.10⅜	56. 1½	18.2⅜	57. 2	18.6⅜	58. 2⅝
17.6½	55. 1¼	17.10½	56. 1⅞	18.2½	57. 2⅜	18.6½	58. 3
17.6⅝	55. 1⅝	17.10⅝	56. 2¼	18.2⅝	57. 2⅞	18.6⅝	58. 3⅜
17.6¾	55. 2	17.10¾	56. 2⅝	18.2¾	57. 3¼	18.6¾	58. 3¾
17.6⅞	55. 2½	17.10⅞	56. 3	18.2⅞	57. 3⅝	18.6⅞	58. 4⅛
17.7	55. 2⅞	17.11	56. 3⅜	18.3	57. 4	18.7	58. 4½
17.7⅛	55. 3¼	17.11⅛	56. 3⅞	18.3⅛	57. 4⅜	18.7⅛	58. 4⅞
17.7¼	55. 3⅝	17.11¼	56. 4¼	18.3¼	57. 4¾	18.7¼	58. 5⅜
17.7⅜	55. 4	17.11⅜	56. 4⅝	18.3⅜	57. 5⅛	18.7⅜	58. 5¾
17.7½	55. 4⅜	17.11½	56. 5	18.3½	57. 5½	18.7½	58. 6⅛
17.7⅝	55. 4⅞	17.11⅝	56. 5⅜	18.3⅝	57. 6	18.7⅝	58. 6½
17.7¾	55. 5¼	17.11¾	56. 5¾	18.3¾	57. 6⅜	18.7¾	58. 6⅞
17.7⅞	55. 5⅝	17.11⅞	56. 6⅛	18.3⅞	57. 6¾	18.7⅞	58. 7¼
17. 8	55. 6	18. 0	56. 6½	18.4	57. 7⅛	18.8	58. 7¾
17.8⅛	55. 6⅜	18. 0⅛	56. 7	18.4⅛	57. 7½	18.8⅛	58. 8⅛
17.8¼	55. 6¾	18. 0¼	56. 7⅜	18.4¼	57. 7⅞	18.8¼	58. 8½
17.8⅜	55. 7⅛	18. 0⅜	56. 7¾	18.4⅜	57. 8⅜	18.8⅜	58. 8⅞
17.8½	55. 7½	18. 0½	56. 8⅛	18.4½	57. 8¾	18.8½	58. 9¼
17.8⅝	55. 8	18. 0⅝	56. 8½	18.4⅝	57. 9⅛	18.8⅝	58. 9⅝
17.8¾	55. 8⅜	18. 0¾	56. 8⅞	18.4¾	57. 9½	18.8¾	58.10
17.8⅞	55. 8¾	18. 0⅞	56. 9⅜	18.4⅞	57. 9⅝	18.8⅞	58.10⅜

TABLE NO. 15.—18 ft. 9 in to 20 ft. 0⅞ in.

DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	CIR. FT. IN.	DIAM. FT. IN.	DIAM. FT. IN.
18. 9	58.10⅞	19.1	59.11⅜	19.5	61. 0	19. 9	62. 0½
18. 9⅛	58.11¼	19.1⅛	59.11¾	19.5⅛	61. 0⅜	19. 9⅛	62. 1
18. 9¼	58.11⅝	19.1¼	60. 0⅛	19.5¼	61. 0¾	19. 9¼	62. 1⅜
18. 9⅜	59. 0	19.1⅜	60. 0½	19.5⅜	61. 1⅛	19. 9⅜	62. 1⅝
18. 9½	59. 0⅜	19.1½	60. 1	19.5½	61. 1½	19. 9½	62. 2⅛
18. 9⅝	59. 0¾	19.1⅝	60. 1⅜	19.5⅝	61. 1⅞	19. 9⅝	62. 2½
18. 9¾	59. 1⅛	19.1¾	60. 1¾	19.5¾	61. 2¼	19. 9¾	62. 2⅞
18. 9⅞	59. 1⅝	19.1⅞	60. 2⅛	19.5⅞	61. 2¾	19. 9⅞	62. 3¼
18.10	59. 2	19.2	60. 2½	19.6	61. 3⅛	19.10	62. 3¾
18.10⅛	59. 2⅜	19.2⅛	60. 2⅞	19.6⅛	61. 3½	19.10⅛	62. 4
18.10¼	59. 2¾	19.2¼	60. 3⅜	19.6¼	61. 3⅞	19.10¼	62. 4½
18.10⅜	59. 3⅛	19.2⅜	60. 3¾	19.6⅜	61. 4¼	19.10⅜	62. 4⅞
18.10½	59. 3½	19.2½	60. 4⅛	19.6½	61. 4⅝	19.10½	62. 5¼
18.10⅝	59. 4	19.2⅝	60. 4½	19.6⅝	61. 5	19.10⅝	62. 5⅝
18.10¾	59. 4⅜	19.2¾	60. 4⅞	19.6¾	61. 5½	19.10¾	62. 6
18.10⅞	59. 4¾	19.2⅞	60. 5⅛	19.6⅞	61. 5⅞	19.10⅞	62. 6⅜
18.11	59. 5⅛	19.3	60. 5¾	19.7	61. 6⅛	19.11	62. 6⅞
18.11⅛	59. 5½	19.3⅛	60. 6⅛	19.7⅛	61. 6⅝	19.11⅛	62. 7¼
18.11¼	59. 5⅞	19.3¼	60. 6½	19.7¼	61. 7	19.11¼	62. 7⅝
18.11⅜	59. 6⅜	19.3⅜	60. 6⅞	19.7⅜	61. 7½	19 11⅜	62. 8
18.11½	59. 6¾	19.3½	60. 7¼	19.7½	61. 7⅞	19.11½	62. 8⅜
18.11⅝	59. 7⅛	19.3⅝	60. 7⅝	19.7⅝	61. 8¼	19.11⅝	62. 8¾
18.11¾	59. 7½	19.3¾	60. 8	19.7¾	61. 8⅝	19.11¾	62. 9⅛
18.11⅞	59. 7⅞	19.3⅞	60 8⅜	19.7⅞	61. 9	19.11⅞	62. 9½
19. 0	59. 8⅛	19.4	60. 8⅞	19.8	61. 9⅜	20. 0	62.10
19. 0⅛	59. 8⅝	19.4⅛	60. 9¼	19.8⅛	61. 9¾	20. 0⅛	62.10⅜
19. 0¼	59. 9	19.4¼	60. 9⅝	19.8¼	61.10¼	20. 0¼	62.10¾
19. 0⅜	59. 9½	19.4⅜	60.10	19.8⅜	61.10⅝	20. 0⅜	62.11⅛
19. 0½	59. 9⅞	19.4½	60.10⅜	19.8½	61.11⅛	20. 0½	62.11½
19. 0⅝	59.10¼	19.4⅝	60.10¾	19.8⅝	61.11½	20. 0⅝	62.11⅞
19. 0¾	59.10⅝	19.4¾	60.11⅛	19.8¾	61.11⅞	20. 0¾	63. 0⅜
19. 0⅞	59.11	19.4⅞	60.11⅝	19.8⅞	62. 0⅛	20. 0⅞	63. 0¾

TABLE NO. 16.—Weight of steel per foot.

Square		Round		Octagon	
Size	Lbs.	Size	Lbs.	Size	Lbs.
1/8	.05	1/8	.04	1/8	.04
3/16	.12	3/16	.09	3/16	.10
1/4	.21	1/4	.17	1/4	.18
5/16	.33	5/16	.26	5/16	.28
3/8	.48	3/8	.38	3/8	.40
7/16	.65	7/16	.51	7/16	.54
1/2	.85	1/2	.67	1/2	.70
9/16	1.08	9/16	.85	9/16	.89
5/8	1.33	5/8	1.04	5/8	1.10
11/16	1.61	11/16	1.27	11/16	1.33
3/4	1.92	3/4	1.50	3/4	1.58
13/16	2.24	13/16	1.76	13/16	1.83
7/8	2.60	7/8	2.04	7/8	2.16
15/16	3.06	15/16	2.35	15/16	2.48
1	3.40	1	2.67	1	2.82
1 1/8	4.30	1 1/8	3.38	1 1/8	3.56
1 1/4	5.31	1 1/4	4.17	1 1/4	4.40
1 3/8	6.43	1 3/8	5.05	1 3/8	5.32
1 1/2	7.65	1 1/2	6.01	1 1/2	6.34
1 5/8	8.98	1 5/8	7.05	1 5/8	7 32
1 3/4	10.40	1 3/4	8.18	1 3/4	8 64
1 7/8	11.90	1 7/8	9.38	1 7/8	9.92
2	13.60	2	10.17	2	11.28
2 1/8	15.40	2 1/8	12.05	2 1/8	12.71
2 1/4	17.20	2 1/4	13.60	2 1/4	14.24
2 3/8	19.20	2 3/8	15.10	2 3/8	15.88
2 1/2	21.20	2 1/2	16.68	2 1/2	17.65

TABLE NO. 17.—Weight of steel per foot.

Square		Round.		Octagon	
Size	Lbs.	Size	Lbs.	Size	Lbs.
2⅝	23.50	2⅝	18.39	2⅝	19.45
2¾	25.70	2¾	20.18	2¾	21.28
2⅞	28.20	2⅞	22.06	2⅞	23.28
3	30.60	3	24.10	3	25.36
3⅛	33.13	3⅛	26.12	3⅛	27.50
3¼	35.90	3¼	28.30	3¼	29.28
3⅜	38.54	3⅜	30.45	3⅜	32.10
3½	41.60	3½	32.70	3½	34.56
3⅝	44.57	3⅝	35.20	3⅝	37.05
3¾	47.80	3¾	37.54	3¾	39.68
4	54.40	4	42 72	4	45.12
4¼	61.40	4¼	48.30	4¼	50.84
4½	68.90	4½	54.60	4½	56.90
4¾	76.70	4¾	60.30	4¾	62.52
5	85.00	5	66.80	5	70.60
5¼	93.70	5¼	73.60	5¼	77.80
5½	102.80	5½	80.80	5½	85.15
5¾	112.40	5¾	88.30	5¾	93.12
6	122.40	6	96.10	6	101.45
6½	143.60	6½	113.20	6½	117.12
7	166.40	7	130.80	7	138.24
8	217.60	8	170.88	8	180.48
9	275.60	9	218.40	9	227.84
10	340.00	10	267.20	10	282.40
11	411 20	11	323.00	11	340.60
12	489.60	12	384.40	12	405.80

TABLE NO. 18.—Weight of steel per foot.

Inch	1/8	1/4	3/8	1/2	5/8	3/4	1
1/2	.214	.428	.641	......	......	......	......
5/8	.267	.534	.802	1.069	......	......	......
3/4	.321	.641	.962	1.283	1.603	......	......
7/8	.374	.748	1.122	1.496	1.870	2.244	......
1	.427	.855	1.283	1.710	2.138	2.565	......
1 1/8	.481	.962	1.443	1.924	2.405	2.886	3.848
1 1/4	.534	1.069	1.603	2.138	2.672	3.206	4.275
1 3/8	.588	1.176	1.763	2.351	2.939	3.527	4.703
1 1/2	.641	1.283	1.924	2.565	3.206	3.848	5.130
1 5/8	.695	1.389	2.084	2.779	3.473	4.168	5.558
1 3/4	.748	1.496	2.244	2.993	3.741	4.480	5.985
1 7/8	.802	1.603	2.405	3.206	4.008	4.809	6.413
2	.855	1.710	2.565	3.420	4.275	5.130	6.840
2 1/8	.908	1.817	2.725	3.634	4.542	5.451	7.268
2 1/4	.962	1.924	2.886	3 848	4.809	5.771	7.695
2 3/8	1.015	2.031	3.046	4.061	5.077	6.092	8.123
2 1/2	1.069	2.138	3.206	4.275	5.344	6.413	8.550
2 5/8	1.122	2.244	3.367	4.489	5.611	6.733	8 978
2 3/4	1.176	2 351	3.527	4.703	5.878	7.054	9.405
3	1.283	2.565	3.848	5.130	6.413	7.695	10 260
3 1/4	1.389	2.779	4.168	5.558	6.947	8.336	11.115
3 1/2	1.496	2.993	4.489	5.985	7.481	8.978	11.970
3 3/4	1.603	3.206	4.809	6.413	8.016	9.619	12.825
4	1.710	3.420	5.130	6.840	8 550	10.260	13.680
4 1/4	1.817	3.634	5.451	7.268	9.084	10.901	14.533
4 1/2	1.904	3.848	5.771	7.695	9.619	11.542	15.390
4 3/4	2.031	4.061	6.092	8.123	10.153	12.184	16.245
5	2.138	4.275	6 413	8.550	10.688	12.825	17.100
5 1/4	2.244	4.489	6.733	8.978	11.222	13.466	17.955
5 1/2	2.351	4.703	7.054	9.405	11.756	14.108	18.810
5 3/4	2.458	4.916	7.374	9.833	12.291	14.749	19.665
6	2.565	5.130	7.695	10.260	12.825	15.390	20.520

TABLE NO. 19.—Decimal Equivalents.

Eighths, Sixteenths, Thirty-seconds and Sixty-fourths of an inch for use in connection with Micrometer Calipers.

Eighths

$\frac{1}{8}$ =.125
$\frac{1}{4}$ =.250
$\frac{3}{8}$ =.375
$\frac{1}{2}$ =.500
$\frac{5}{8}$ =.625
$\frac{3}{4}$ =.750
$\frac{7}{8}$ =.875

Sixteenths

$\frac{1}{16}$=.0625
$\frac{3}{16}$=.1875
$\frac{5}{16}$=.3125
$\frac{7}{16}$= 4375
$\frac{9}{16}$=.5625
$\frac{11}{16}$=.6875
$\frac{13}{16}$=.8125
$\frac{15}{16}$=.9374

Thirty-seconds

$\frac{1}{32}$=.03125
$\frac{3}{32}$=.09375
$\frac{5}{32}$=.15625
$\frac{7}{32}$=.21875
$\frac{9}{32}$=.28125

Thirty-seconds Con.

$\frac{11}{32}$=.34375
$\frac{13}{32}$=.40625
$\frac{15}{32}$=.46875
$\frac{17}{32}$=.53125
$\frac{19}{32}$= 59375
$\frac{21}{32}$=.65625
$\frac{23}{32}$=.71875
$\frac{25}{32}$=.78125
$\frac{27}{32}$=.84375
$\frac{29}{32}$=.90625
$\frac{31}{32}$=.96875

Sixty-fourths

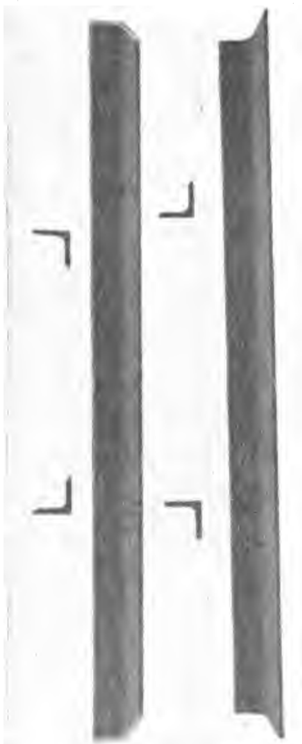
$\frac{1}{64}$=.015625
$\frac{3}{64}$=.046875
$\frac{5}{64}$=.078125
$\frac{7}{64}$=.109375
$\frac{9}{64}$=.140625
$\frac{11}{64}$=.171875
$\frac{13}{64}$=.203125
$\frac{15}{64}$=.234375
$\frac{17}{64}$=.265625
$\frac{19}{64}$=.296875

Sixty-fourths Con.

$\frac{21}{64}$=.328125
$\frac{23}{64}$=.359375
$\frac{25}{64}$=.390625
$\frac{27}{64}$=.421875
$\frac{29}{64}$=.453125
$\frac{31}{64}$=.484375
$\frac{33}{64}$=.515625
$\frac{35}{64}$=.546875
$\frac{37}{64}$=.578125
$\frac{39}{64}$=.600375
$\frac{41}{64}$=.640625
$\frac{43}{64}$=.671875
$\frac{45}{64}$=.703125
$\frac{47}{64}$=.734375
$\frac{49}{64}$=.765625
$\frac{51}{64}$=.796875
$\frac{53}{64}$=.828125
$\frac{55}{64}$=.859375
$\frac{57}{64}$=.890625
$\frac{59}{64}$=.921875
$\frac{61}{64}$=.953125
$\frac{63}{64}$=.984375

TABLE NO. 20.—U. S. Standard Bolts and Nuts.

Diam. of Bolt... Inches	No. of thre'ds per Inch	Diam. of hole in nut... Inches	Diam. of hole in nut... Ins.	Diam. of head & nut... Ins.	Thickness of head... Ins.	Thickness of nut... Ins.	Length Iron reqd. to Form Square Head... Inches
3/16	24	.156	5/32	5/16	1/8	3/16	1/2
1/4	20	.185	13/64	7/16	3/16	1/4	5/8
3/8	16	.294	5/16	11/16	5/16	3/8	1 1/16
7/16	14	.344	11/32	3/4	3/8	7/16	1 1/4
1/2	13	.400	13/32	7/8	7/16	1/2	1 3/8
9/16	12	.454	15/32	1	1/2	9/16	1 9/16
5/8	11	.507	17/32	1 1/8	9/16	5/8	1 3/4
3/4	10	.620	21/32	1 1/4	5/8	3/4	2
7/8	9	.731	3/4	1 1/2	3/4	7/8	2 3/8
1	8	.873	27/32	1 5/8	7/8	1	2 5/8
1 1/8	7	.940	31/32	1 13/16	1	1 1/8	3
1 1/4	7	1.065	1 6/32	2	1 1/8	1 1/4	3 1/4
1 3/8	6	1.160	1 7/32	2 3/16	1 1/4	1 3/8	3 1/2
1 1/2	6	1.284	1 5/16	2 5/16	1 3/8	1 1/2	3 3/4
1 5/8	5 1/2	1,389	1 7/16	2 7/16	1 1/2	1 5/8	4 1/4
1 3/4	5	1.490	1 17/32	2 3/4	1 5/8	1 3/4	4 1/2
1 7/8	5	1.615	1 5/8	2 7/8	1 3/4	1 7/8	4 7/8
2	4 1/2	1.712	1 25/32	3 1/8	1 7/8	2	5 1/8
2 1/4	4 1/2	1.962	1 31/32	3 1/2	2	2 1/4	5 7/8
2 1/2	4	2.175	2 11/64	3 7/8	2 1/4	2 1/2	6 3/8
2 3/4	4	2.425	2 27/64	4 1/8	2 1/2	2 3/4	7
3	3 1/2	2.628	2 5/8	4 5/8	2 3/4	3	7 5/8
3 1/4	3 1/2	2.878	2 27/32	4 7/8	3 1/8	3 1/4	8 1/8
3 1/2	3 1/4	3.100	3 3/32	5 3/8	3 1/4	3 1/2	8 5/8
3 3/4	3	3.317	3 5/16	5 3/4	3 1/2	3 3/4	9 1/2
4	3	3.566	3 9/16	6 1/8	3 3/4	4	10 1/8
4 1/4	2 7/8	3.825	3 13/16	6 1/2	4	4 1/4	10 3/4
4 1/2	2 3/4	4.027	4 1/32	6 7/8	4 1/4	4 1/2	11 1/4
4 3/4	2 5/8	4.255	4 1/4	7 1/4	4 1/2	4 3/4	12
5	2 1/2	4.480	4 1/2	7 5/8	4 3/4	5	12 5/8
5 1/4	2 1/2	4.730	4 3/4	7 7/8	5	5 1/4	13 1/4
5 1/2	2 3/8	5.053	5 1/32	8 3/8	5 1/4	5 1/2	13 7/8
5 3/4	2 3/8	5.203	5 1/4	8 3/4	5 1/2	5 3/4	14 1/2
6	2 1/4	5.423	5 7/16	9 1/8	5 3/4	6	15 1/8



The above cut shows how angles should be cut for inside and outside rings.

The lower angle is for a ring with the flange on the outside, which is called an outside ring. The upper angle is cut for a ring with the flange on the inside, which is called an inside ring.

RULES FOR WORKING ANGLE IRON.

The above cut shows how angles should be cut for inside and outside rings.

The lower angle is for a ring with the flange on the outside, which is called an outside ring. The upper angle is cut for a ring with the flange on the inside, which is called an inside ring.

The rule governing the making of rings from angle iron is much different from the rules governing the making of rings from all other material. Nearly every blacksmith has a rule of his own, but in cutting off material he usually cuts it off about ten inches longer than the required length. There is only one correct rule for angle iron, one for norway and one for steel.

Rule No. 21, Common Angle Iron.

To find the circumference of a ring with the flange out, called an outside ring, the diameter of which is given, multiply the diameter by 3.1416 or refer to tables.

To the circumference add twice the width of the flange of the material used, which will give the required length of the piece to be cut off. Cut a bevel on each end of the outside flange, keeping the inside square.

The width of the bevel to be cut depends on the width of the flange. If the flange is two inches wide a bevel of one inch must be cut, if three inches, a bevel

of one and one-half inches must be cut; if four inches, a bevel of two inches must be cut, etc., cutting a bevel on each end of just half the width of the flange. When the piece is trimmed off at both ends the inside flange will measure once the width of the flange, shorter than the outside flange. Bend both ends to the required circle, from four to six inches back. Heat in furnace and bend on former. When bent both ends will stand apart to allow for a V.

Example: To make an outside ring of 21″ diameter of angle iron 2″x2″, multiply the diameter, 21″, by 3.1416, which gives 65.9736, but as this is but a fraction less than 66″, the 66″ is close enough to work to. As the width of the flange is 2″, take twice this, which is four inches, and add to the circumference of 66″, which gives 70″, the length of the piece to be cut off. Cut a bevel of 1″ on each end of the outside flange, keeping the inside square. This will make the inside flange measure 68″, or two inches shorter than the outside flange, which measures 70″.

Bend both ends to the 21″ circle, about 4″ back. Heat in furnace and bend on former. When bent both ends will stand apart to allow for a V.

The rule governing the making of a ring, with the flange on the inside, which is called an inside ring, is just the reverse of the rule for the making of an outside ring.

First, find the circumgerence as in rule for making

outside ring. From this deduct twice the width of the flange used. Cut a bevel of one-half the width of the flange, on each end of the inside flange, keeping outside square. When cut to bevel the inside flange will measure two inches shorter than the outside flange. Bend both ends to the required circle, from four to six inches back. Heat, bend and turn on former.

Example: To make an inside ring of 21″ diameter of angle iron 2″x2″. The circumference is 66″. Twice the width of the flange is 4″. The 4″ deducted from the 66″ leaves 62″, the length of the piece to be cut off. Cut a bevel of 1″ on each end of the inside flange, making it two inches shorter than the outside flange. Bend to the 21″ circle, about 4″ back. Heat in furnace and turn on former.

Rule No. 2, Angle Steel—Outside Rings.

For outside rings, angle steel requires more length than common angle iron, but there is not much common iron used now, it is mostly steel.

The reason that it takes more length of angle steel is that steel will not stretch as will common iron, but gathers more at the heel.

To make an outside ring find the circumference as instructed in rule No. 1. To this add two and one-half times the width of the flange. Cut a bevel of one-half the width of the flange on both ends of the outside

flange, leaving the inside square. Bend, heat and turn on former.

Example: To make an outside ring of 21″ diameter of angle steel 2″x2″. The circumference is 66″. Two and one-half times the width of the flanges is 5″. The 5″ added to the 66″ gives 71″, the length of the piece to be cut off. Cut a bevel of one inch on each end of the outside flange, keeping the inside square. This will make the inside flange measure two inches shorter than the outside flange. Bend, heat and turn on former.

To Make an Inside Ring.

Find the circumference as instructed in rule No. 1. From this deduct only twice the width of the flange. The reason for deducting only twice the width of the flange for an inside ring, when two and one-half times the width is added for an outside ring, is that steel gathers more on the inside of the flange, as the heel will not stretch. Cut a bevel of one-half the width of the flange on each end of the inside flange, leaving the outside square. Bend, heat and turn on former.

Example: To make an inside ring of 21″ diameter of angle steel 3″x3″. The circumference is 66″. Twice the width of the flange is 6″. The 6″ deducted from the 66″ leaves 60″, the length of the piece to be cut off. Cut a bevel of 1½″ on each end of the inside flange, leaving the outside square. This will make the

inside flange measure three inches shorter than on the outside flange.

Bend to the 21″ circle, about 4″ back. Heat and turn on former.

Rule No. 3—Norway—Outside Rings.

Norway iron requires more length than either common iron or steel. It is so soft and tough and so much heavier at the heel, and contains so much more heat that it will gather at the heel before it will stretch at the outer edge.

To Make an Outside Ring of Norway Iron.

Find the circumference as indicated in rule one. To this add three times the width of the flange. Cut a bevel of one-half the width of the flange on each end of the outside flange. This will make the inside flange once the width of the flange shorter than the outside flange. Bend to the required circle from four to six inches back, heat and turn on former.

Example: To make an outside ring of 21″ diameter of norway 2″x2″. The circumference is 66″. Three times the width of the flange is 6″. The 6″ added to the 66″ gives 72″, the length of the piece to be cut off. Cut a bevel of 1″ on each end of the outside flange, leaving inside square. Bend to the 21″ circle, about 4″ back, heat and turn on former.

Inside Rings.

To make an inside ring, first find the circumference as in rule one. From this deduct two and one-half times the width of the flange. Cut a bevel of one-half the width of the flange on each end of the inside flange, leaving the outside square. Bend to the required circle, heat and turn on former.

Example: To make an inside ring of 21 inch diameter of Norway 2x2 inch, the circumference is 66 inches. Two and one-half times the width of the flange is 5 inches; deducted from the 66 inches leaves 61 inches, the length of the piece to be cut off. Cut a bend of one inch on each end of the inside flange, keeping outside square. Bend the 21 inch circle about 4 inches back. Heat and turn on former.

One thing that should be borne in mind is that all inside rings should be turned a shade smaller and all outside rings a shade larger than the given size. If it is found necessary to open an inside ring out a little don't heat it, but lay it flat on the block and draw it a little on the inside of flange. In this way it can be drawn out ½ inch if required. An outside ring can also be made smaller in the same manner, by drawing it on the outside flange. In bending rings care should be taken to hammer them as little as possible, as the more a ring is hammered the worse for the ring. If

good judgment is used it doesn't require much hammering to keep a ring in shape.

When cutting off material to make rings of flat, square or round iron, always allow what stuff will be wasted in welding. As some blacksmiths require more length than others, no absolute rule can be made, but each must judge for himself what length to allow for waste.

RULE NO. 4.—WEIGHTS.

A simple rule, which all blacksmiths should know, is the rule for finding the weight of a piece of steel of any given length or size.

One foot of 1 inch round steel weighs 2.67 pounds, therefore to find the weight of any given size multiply the diameter by itself and multiply this by 2.67 pounds; this will give the weight of one foot, then multiply by the number of feet and you will have the weight of the entire piece.

Example: One foot of 2 inch round steel weighs 2x2x2.67 pounds, which is 10.68 pounds.

One foot of 3 inch steel weighs 3x3x2.67 pounds, which is 24.03 pounds.

One foot of 1 inch square steel weighs 3.40 pounds, therefore to find the weight of any given size, multiply the square by the square and multiply this by 3.40, which will give the weight of one foot, then mul-

tiply this product by the number of feet, which will give the weight of the entire piece.

Example: One foot of 2 inch square steel weighs 2x2x3.40 pounds, which is 13.60 pounds.

One foot of 3 inch square steel weighs 3x3x3.40 pounds, which is 30.60 pounds.

RULE NO. 5—SHACKLES.

Standard Shackles: The size of a standard shackle is determined by the size of the iron from which it is made. Thus a 2 inch shackle is one made from 2 inch iron, a 3 inch shackle is one made from 3 inch iron, a 4 inch shackle is one made from 4 inch iron, etc. To make a standard shackle requires 16 times the thickness of the iron used. When shaped, turned and both eyes are welded, you have a standard shackle.

To make a bow shackle add one inch to the length of the piece to be cut off.

Standard Hooks.

The size of a standard hook is also determined by the size of the iron from which it is made.

It requires eight times the thickness of the iron used; thus, a 2 inch hook requires a piece of iron 16 inches long, and a 3 inch hook requires a piece 24 inches long, etc.

Standard Chain Links.

To make a standard link requires twice the length of the link, to which is added five times the thickness of the iron used. Turn, shape and weld and you have a standard link.

Example: To make a 6 inch standard link of one inch iron; twice the length is 12 inches, five times the thickness is 5 inches; 12 inches added to 5 inches gives 17 inches, the length of the piece to be cut off. Turn, shape and weld.

THE REAL INVENTOR OF THE BESSEMER PROCESS.

William C. Kelly, inventor of the Bessemer process of making steel, who died a few years ago at Louisville, Ky., was years ago the proprietor of the Suawanee Iron Works and Iron Forge, in Lyon county, Ky. The metal produced at these works was taken from the furnace to the forge, where it was converted into charcoal blooms. These blooms had a great reputation for durability and quality, and were used principally for boiler plates. It was while making the blooms at this place that Mr. Kelly made his great invention of converting iron into what is now called "Bessemer Steel." The old process of making blooms was very expensive owing to the great amount of charcoal required for its transformation, and Mr. Kelly

conceived the idea of converting the metal into charcoal blooms without the use of fuel, by simply forcing powerful blasts of air up through the molten metal. His idea was that oxygen of the air would unite with the carbon in the metal and thus produce combustion, refine the metal, and by eliminating the carbon, wrought iron or steel would be produced. When he announced his theory to his friends and to skilled iron workers they scoffed and were struck with astonishment that a man of Mr. Kelly's learning, practice and iron making knowledge would suggest such an idea as boiling metal without the use of fuel, and by simply blowing air through it. His friends thought him demented, tried to discourage him from wasting his time and money upon such a visionary scheme. Mr. Kelly was confident that his idea was correct and a good one, and began making experiments, which he kept up with varying success for ten years, but the blooms were manufactured without the use of fuel. It was generally known as "Kelly's Air Boiling Process," and was in daily use at his works. Mr. Kelly's customers learned of his process, and not understanding it, they advised him that they would not buy blooms made by any but the old established method. This was the first difficulty placed in Mr. Kelly's way, and he was consequently compelled to carry on his work secretly, which subjected it to many disadvantages.

Some English skilled workmen in Mr. Kelly's employ were familiar with his non-fuel process and went back to England, taking the secret with them. Shortly after their arrival in Liverpool, Henry Bessemer, an English iron manufacturer, startled the iron world by anonuncing the same process as Mr. Kelly's, and applied for patents in England and the United States. Mr. Kelly at once applied for a patent, and was granted one over Bessemer, the decision being that he was the first inventor and was entitled to the patent by priority. The history of this remarkable invention is a lengthy one, and it is generally admitted by persons familiar with the case that Bessemer's idea was secured from the English iron workers who had been in Mr. Kelly's employ. Certain it is, however, that Mr. Kelly's invention and patents have heaped honors and wealth upon Bessemer, and he has been regarded as the greatest inventor of the 19th century, and the credit has always been accorded him. Mr. Kelly's process was barely successful until after it was perfected by Robert Musshult, a prominent English iron worker. Concerning the claims of the different persons, the late James Park, of Pittsburg, once said: "The world will some day learn the truth, and in ages to come a wreath of fame will crown William Kelly, the true inventor, that will never be effaced by time."

TOUGHENING SOFT STEEL.

Articles made of soft steel, Bessemer Open Heat or low carbon crucible steel can be greatly improved by simply heating them red hot and cooling them in oil. Cut gears made of soft steel, which have received this treatment, will wear much longer and the teeth cannot be broken off. We often see a steel cut gear with broken teeth. To test this process take one of these broken gears, heat it red hot, and cool it in oil. When cold put in a vice, take a hammer and try to knock out a tooth. You will find it to be impossible. This process does not harden or soften this grade of steel, but it toughens it in a remarkable manner. This secret is worth a great deal to every blacksmith and machinist and is of more value to manufacturers.

ADVICE TO YOUNG MECHANICS.

Watch and learn. This is an excellent motto for every young man to adopt, and by a close observance if it, it will prove of great value to him all through life. There is no surer way of gaining knowledge than by a careful watchfulness of others in the same line of business as yourself. As an apprentice you are not expected to know everything, and the best way to gain information from others is to show a willingness to learn, then they will take an interest in teaching you. But if, as is often the case, a young man, after he has worked at the trade a few months, pretends to know as much, and sometimes a great deal more, than those much older and more experienced than himself, he will not get much information from his fellow workmen; neither will he retain their good will and may expect to have all sorts of jokes played upon him.

As a journeyman, if you are intelligent, you will very often have occasion to see that you do not know it all, and in fact, the longer you live the more you learn, the more you find that there is always more to be learned. The egotistical, loud mouthed man is generally very far from being as near perfection as he would like to have others think him. The man who, on first acquaintance, is anxious to tell you what he knows, and is free in giving advice and information without being asked, generally exhausts the supply

before long. The man who is willing to listen is generally the one whose source of information is broader and of a more durable, valuable and substantial kind.

An example may prove the idea to be conveyed more clearly. Several years ago I was employed as toolsmith in a large shop. Soon after I went there, there was a vacancy on the fire next to me. The foreman wanted to hire a good, practical and experienced man for general light work. A well dressed young man applied for the position. He was very certain that he knew all about the class of work and was engaged. It was not long before every man in the shop knew all that he did, and one valuable thing which he did not, and that was that he did not know as much as he pretended to. His swelled head and big mouth soon got the men down on him. The first week he worked on some common repair jobs which an apprentice of six months' experience could have done with ease.

The next week the foreman set him to making bolts. They were 1½ inch Bessemer steel and were to have the heads welded on. He cut off the stock and bent the collars, but when he came to weld them they would not stick. He tried five or six heats, but without success. He then seemed to think there was something the matter with the fire, so the helper had to build a new fire, and he tried again, but with no better results. He commenced to get excited and curse the

coal and his helper. All the men in the shop were watching him and laughing to see him sweat and hear him swear. After trying his luck on another bolt, he went to the foreman and told him that he could not work with that helper and such rotten coal. The foreman went over to his fire and with the same helper welded the heads on the two bolts he had been trying and two or three others. The foreman told him that he could see nothing wrong with either the helper or the fire. That made the chap look sick, but he took courage and tried again with no better success. He finally gave it up and quit the job to save the foreman the trouble of discharging him. The foreman watched him as he passed out of the gate never to return. He then said to me, "That young man got smart too soon." That young man never worked in a blacksmith shop again. The last time I saw him he was trying to be a life insurance agent. How he succeeded I do not know, but I know it is poor policy to get smart too soon and it sometimes pays to be a little ignorant. Anyhow, a little modesty is a good thing to take with you when going to a new place. If you know more than you pretend it will soon be found out and you will be the gainer, but if you fail to make good your pretensions, not only your employer, but your fellow workmen will be down on you and things will be correspondingly unpleasant. When starting at a new job you must ex-

pect all the men in the shop to keep an eye on you for the first day or two; (that is only natural); they want to know what sort of a workman you are and how you do different jobs, and they have a right to size you up, and they will not fail to do it; but don't let that trouble you; go ahead and don't get excited. Take the thing cool until you get accustomed to your surroundings. Of course the forge and everything else is different than the outfit you have been accustomed to, the work and the helper may also be strange to you. Taking everything into consideration it is a trying position for a man who has worked in but a few shops, and especially so for a young man whose experience is limited. If you get excited and lose your head you are sure to make a fizzle of everything you undertake. The men will have a good laugh at you and the foreman will think you are a four-flusher instead of a blacksmith and may discharge you before you have time to convince him otherwise. Keep cool and adapt yourself to new surroundings. Keep your eyes on your work and don't look around the shop every minute to see who is watching you. Go about your work just as though you were the only blacksmith in the shop, then you will not get excited, the men will have no laugh coming at your expense and the foreman will not be disappointed with you. Never tell your shop mates about any wonderful jobs you have done, for they will do as

they please about believing it. When you do a fine job never call anyone's attention to it or stand and look at it after it is finished. If you do the men will naturally suppose it was the first decent job you ever happened to make. The boss and all the men will soon know just what sort of a workman you are. If you are an expert they will find it out in due time, but if you are not qualified to hold the job they will know it too soon.

Never waste any wind telling what you can do or criticising what others do. What you do will speak for itself. What men see they will believe and not soon forget, be it good or bad.

Never take any stock in what the men tell you about the boss. Wait and find out for yourself, and when you find out keep what you know under your own hat. If you don't like the boss or the job don't suit you, resign and get a position that will be more satisfactory.

Never allow yourself to become a knocker and never listen to one. The man that knocks is a sore head, a block head, a chronic kicker and the south end of a horse going north, and is very apt to be a liar. Never slight your work and don't put any more time on a job than is necessary to do it right. Strive to be skillful. An awkward workman is invariably a bungler and a slow workman. Never gets the top wages. Read all the mechanical books and papers you can get. Keep regular hours and good company. Also keep sober and remember the Golden Rule.

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